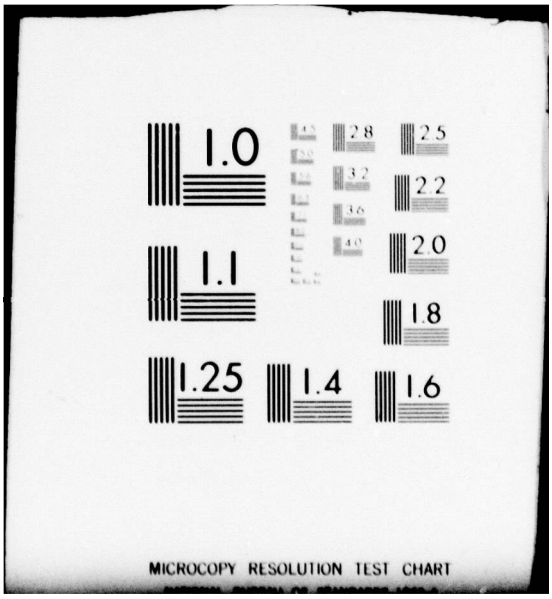
AD-A073 817 COASTAL ENGINEERING RESEARCH CENTER FORT BELVOIR VA F/G 8/7
SAND RESOURCES OF SOUTHEASTERN LAKE MICHIGAN.(U)
JUL 79 E P MEISBURGER, S J WILLIAMS
UNCLASSIFIED CERC-MR-79-3 NL

1 OF 1
AD A073817

END
DATE FILMED
10-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

LEVEL II

MR 79-3

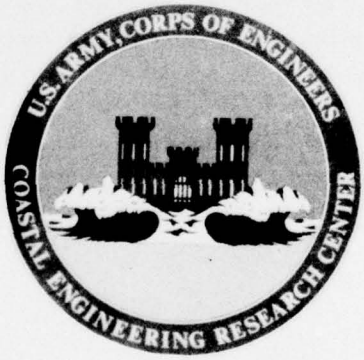
Sand Resources of Southeastern Lake Michigan

AD A073817

by
Edward P. Meisburger, S. Jeffress Williams,
and Dennis A. Prins

MISCELLANEOUS REPORT NO. 79-3
JULY 1979

DDC
RECEIVED
SEP 17 1979
C



DDC FILE COPY

Approved for public release;
distribution unlimited.

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER
Kingman Building
Fort Belvoir, Va. 22060

79 09 14 027

Reprint or republication of any of this material shall give appropriate credit to the U.S. Army Coastal Engineering Research Center.

Limited free distribution within the United States of single copies of this publication has been made by this Center. Additional copies are available from:

National Technical Information Service
ATTN: Operations Division
5285 Port Royal Road
Springfield, Virginia 22161

Contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(14) CERC — REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: MR-79-3	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: (9)	
4. TITLE (and Subtitle): (6) SAND RESOURCES OF SOUTHEASTERN LAKE MICHIGAN	5. TYPE OF REPORT & PERIOD COVERED: Miscellaneous Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Edward P. Meisburger, S. Jeffress Williams, Dennis A. Prins	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Department of the Army, Coastal Engineering Research Center (CERRN-GE), Kingman Building, Fort Belvoir, Virginia 22060	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: D31466
11. CONTROLLING OFFICE NAME AND ADDRESS: Department of the Army, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, Virginia 22060 (11)	12. REPORT DATE: July 1979
	13. NUMBER OF PAGES: 61
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 63p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Geomorphology
Lake Michigan
Sand resources
Sediments
Seismic reflection

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

About 2,072 square kilometers (800 square miles) of the eastern shore of Lake Michigan between Manistee, Michigan, and Burns Harbor, Indiana, was surveyed to assess potential sand and gravel resources. The survey data consist of 915 kilometers (569 miles) of high-resolution seismic reflection profiles, side-scan sonar records, and 93 cores a maximum of 6.1 meters (20 feet) long. Bathymetric survey limits are the -3.7-meter (-12 feet) contour lakeward to about the -37-meter (-120 feet) contour. The most common sediment types found

(continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

037 050 79 09 14 027

CONT'

are clean, fine to coarse quartz sand and silt and clay. Sand appears to predominate in surface deposits and to be the primary constituent of shoals and ridges present in several locales. Silt and clay deposits are the most common subbottom sediment type; clay, gravel, and till-like mixtures of sandy-silty pebbles occur locally. Indurated shale occurs in the area near New Buffalo, Michigan. Results show that the highest potential for sand is in the area between Whitehall and Saugatuck, Michigan. Smaller deposits appear to occur between Manistee and Whitehall, Michigan, and from Saugatuck to 15 kilometers (9.3 miles) south of Benton Harbor, Michigan. The region with lowest potential for sand resources is from Benton Harbor south to Burns Harbor, Indiana, where a thin veneer of sand overlies silt and clay.

Accession For
NTIS GRA&I
DDC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or special
A

PREFACE

This report on sand resources of southeastern Lake Michigan is one of a series which presents results of the Inner Continental Shelf Sediment and Structure (ICONS) study. The primary objective of the ICONS study is to locate offshore sand and gravel deposits suitable for beach nourishment and restoration. The work is carried out under the coastal processes program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by Edward P. Meisburger, S. Jeffress Williams, and Dennis A. Prins, under the general supervision of Dr. C.H. Everts, Chief, Geotechnical Engineering Branch. The manuscript was reviewed by Dr. Everts and Dr. R.M. Sorensen (at the time Acting Chief, Engineering Development Division).

Data collection was conducted by CERC with the assistance of three U.S. Army Engineer Districts (Chicago, Detroit, and Mobile) and the U.S. Army Engineer Waterways Experiment Station.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Ted E. Bishop

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

CONTENTS

		Page
	CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)	6
I	INTRODUCTION	7
II	PROCEDURES	7
	1. Seismic Survey	7
	2. Core Boring	15
	3. Navigation Control	15
III	RESULTS	16
	1. Geologic Character of the Study Area	16
	2. Segment Description	19
IV	SUMMARY	29
APPENDIX		
A	SEISMIC REFLECTION PROFILES	31
B	CORE LOGS	39
C	GRANULOMETRIC DATA	56

TABLES

	Grain-size scales (soil classification)	18

FIGURES

1	Lake Michigan study area	8
2	Survey coverage map 1 area	9
3	Survey coverage map 2 area	10
4	Survey coverage map 3 area	11
5	Survey coverage map 4 area	12
6	Survey coverage map 5 area	13
7	Survey coverage map 6 area	14
8	Bathymetry and sand potential, segment division 1, map 1 area	20
9	Bathymetry and sand potential, segment divisions 2 to 6, map 2 area	21
10	Bathymetry and sand potential, segment divisions 7 to 11, map 3 area	22

CONTENTS

FIGURES--Continued

		Page
11	Bathymetry and sand potential, segment divisions 12, 13, and 14, map 4 area.	23
12	Bathymetry and sand potential, segment divisions 15 to 19, map 5 area.	24
13	Bathymetry and sand potential, segment divisions 19 and 20, map 6 area.	25

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.
To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

SAND RESOURCES OF SOUTHEASTERN LAKE MICHIGAN

by
Edward P. Meisburger, S. Jeffress Williams, and Dennis A. Prins

I. INTRODUCTION

The construction, improvement, and periodic maintenance of beaches and dunes by placement of suitable sand along the shoreline is an important means of counteracting coastal erosion and of enhancing coastal recreational facilities (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977).[1] In recent years, it has become increasingly difficult to obtain large volumes of suitable sand from lagoons and inland sources because of diminishing resources as well as economic and ecological factors. Accordingly, the Coastal Engineering Research Center (CERC) initiated an Inner Continental Shelf Sediment and Structure (ICONS) study to locate offshore sand resources suitable for beach fill. This report deals with the location and physical characteristics of offshore sand resources in parts of eastern and southern Lake Michigan.

A zone adjacent to the shore about 4.8 to 9.7 kilometers (3 to 6 miles) wide, extending from Manistee, Michigan, to Burns Harbor, Indiana, constitutes the study area (*Fig. 1*). *Survey coverage of the area is shown* in Figures 2 to 7. Collected data consist of 915 kilometers (569 miles) of reflection profiles and 93 cores ranging from 0.6 to 6.1 meters (2 to 20 feet) in length. In addition, side-scan sonar and low-energy seismic reflection records of each core site were obtained during coring operations. These data were supplemented by pertinent scientific and technical literature and National Ocean Survey (NOS) hydrographic data.

This report is primarily the result of a reconnaissance effort; seismic line spacing and core density are not suitably detailed for reliable delineation of offshore borrow sites. Consequently, denser data coverage and more detailed study of potential borrow sites are needed before final site selection is made for project design and construction.

II. PROCEDURES

1. Seismic Survey.

Seismic reflection profiles were run along the coast of the study area following a zigzag pattern in an onshore-offshore direction (Figs. 2 to 7). Two seismic reflection profiling systems were operated simultaneously during the survey (a high-energy "boomer" system of 0.4 to 14

[1]U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, *Shore Protection Manual*, 3d ed., Vols. I, II, and III, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977, 1,262 pp.

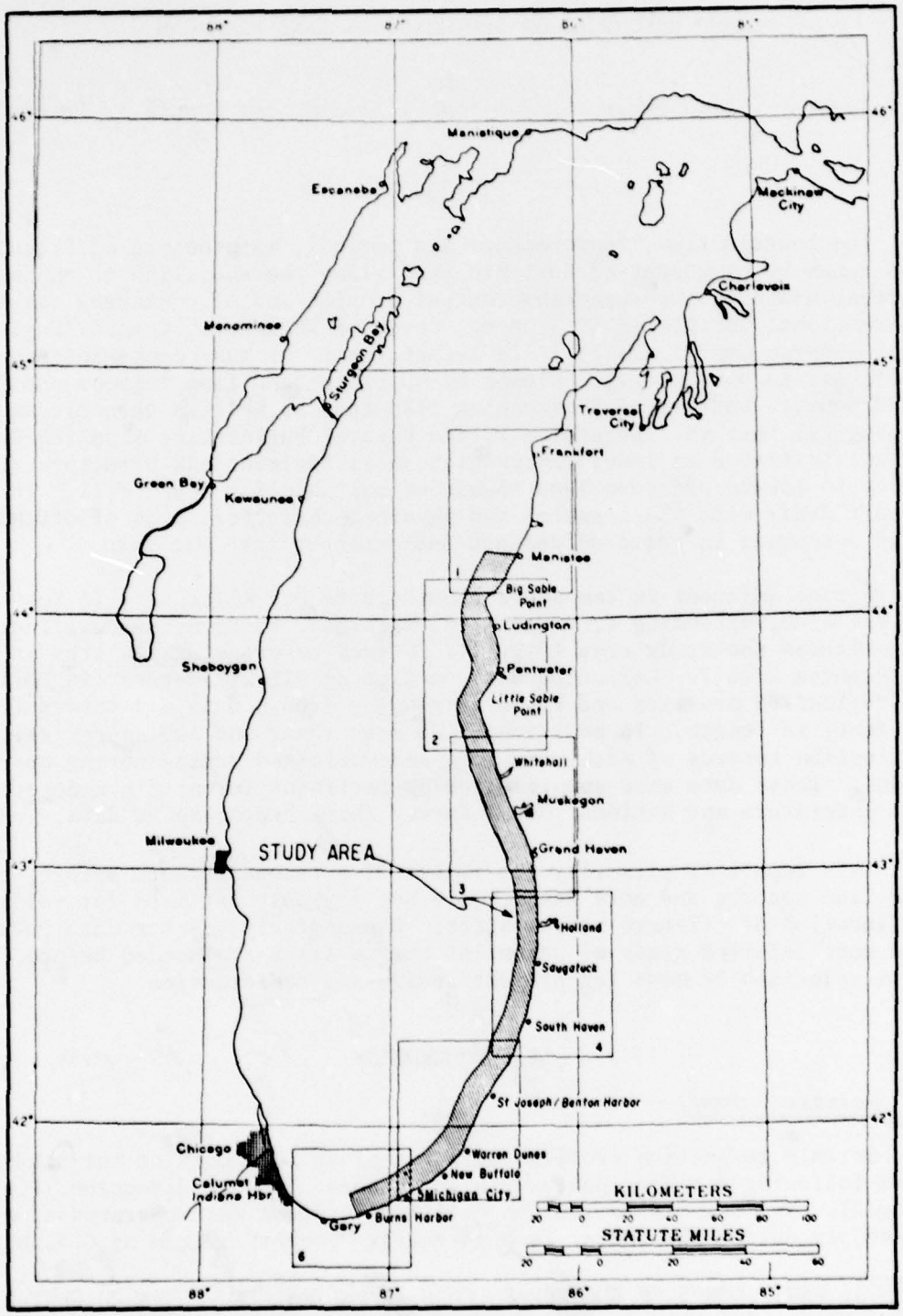


Figure 1. Lake Michigan study area. Location of survey coverage maps and general information maps shown in rectangles.

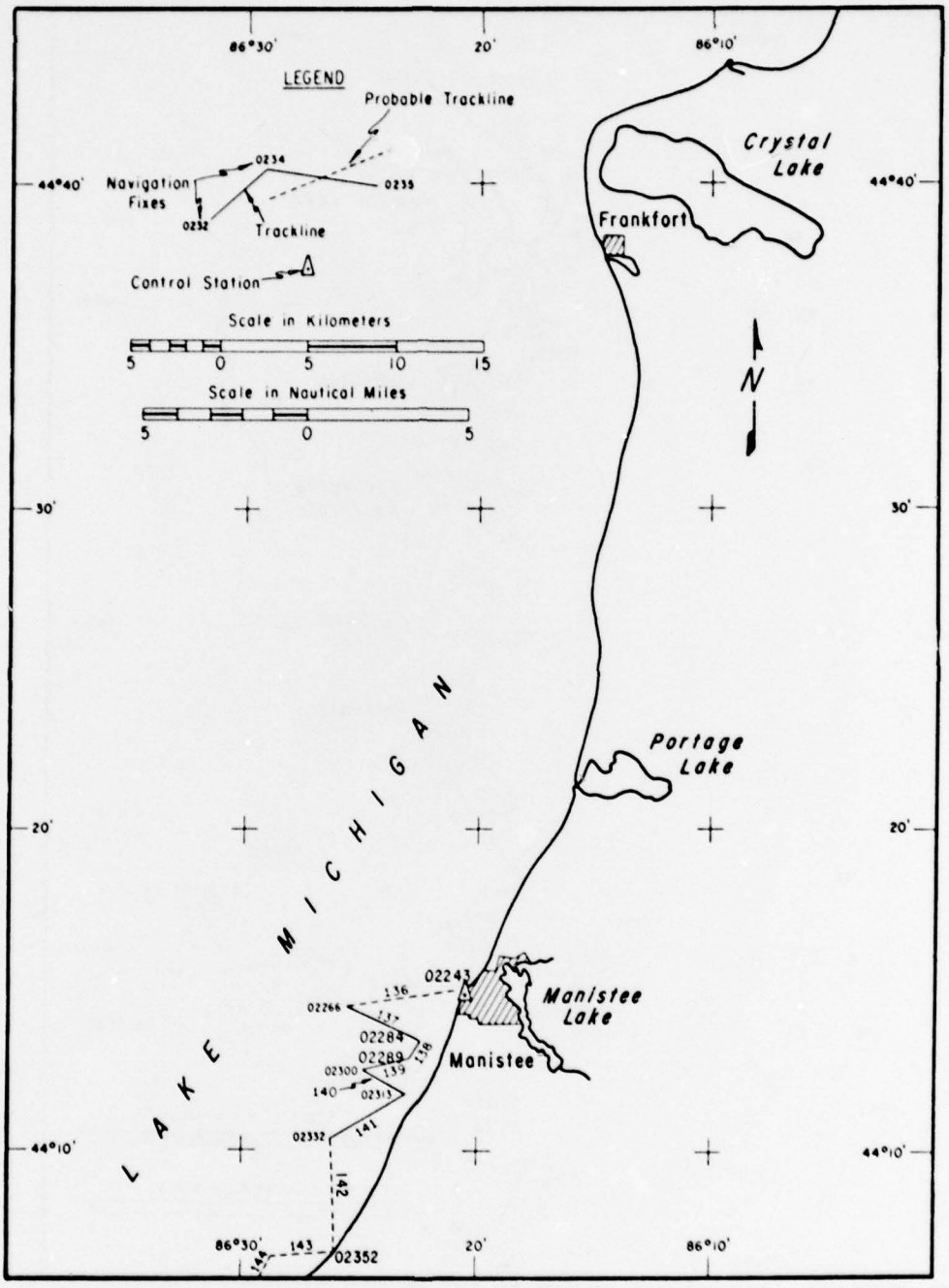


Figure 2. Survey coverage map 1 area.

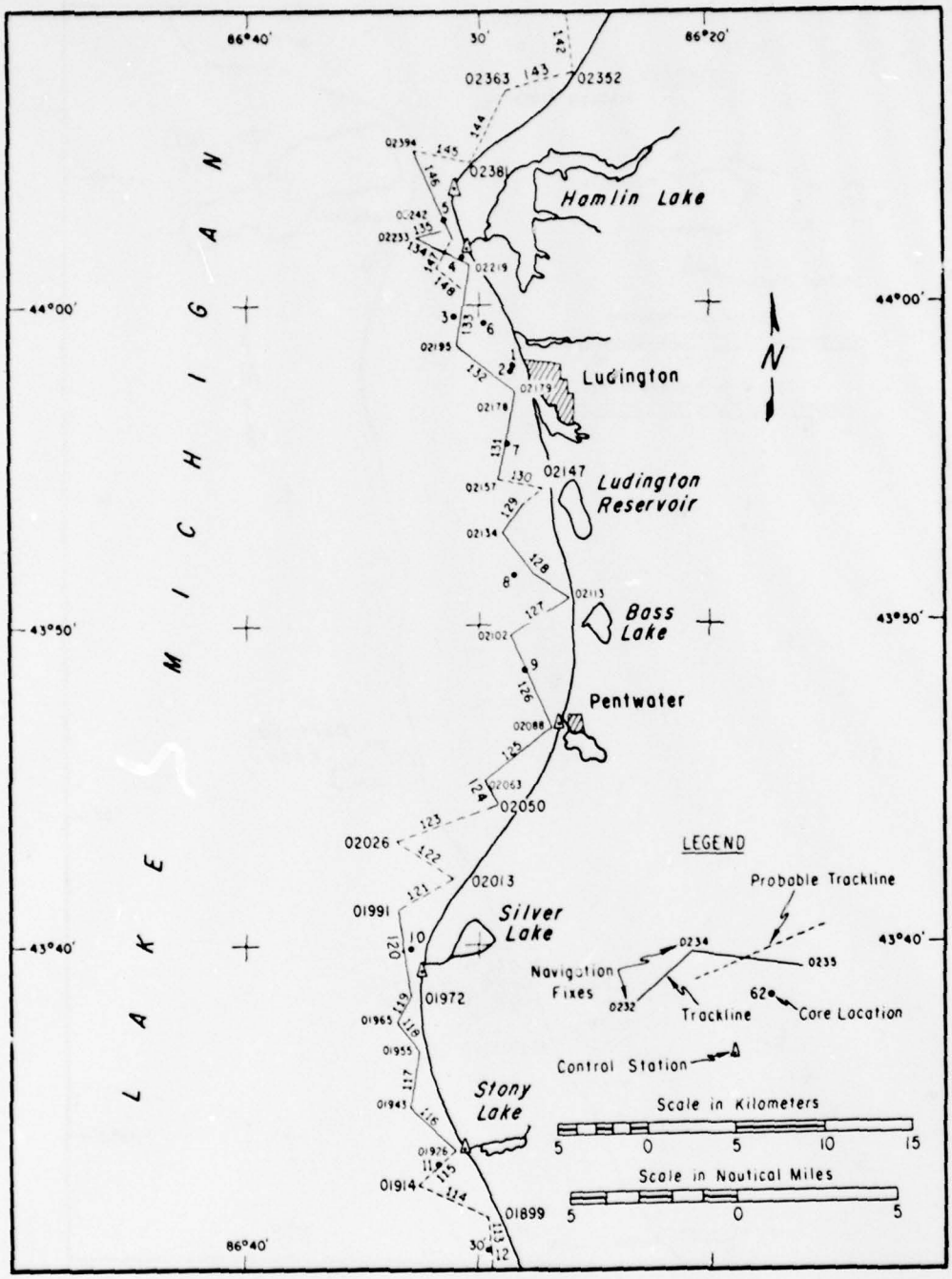


Figure 3. Survey coverage map 2 area.

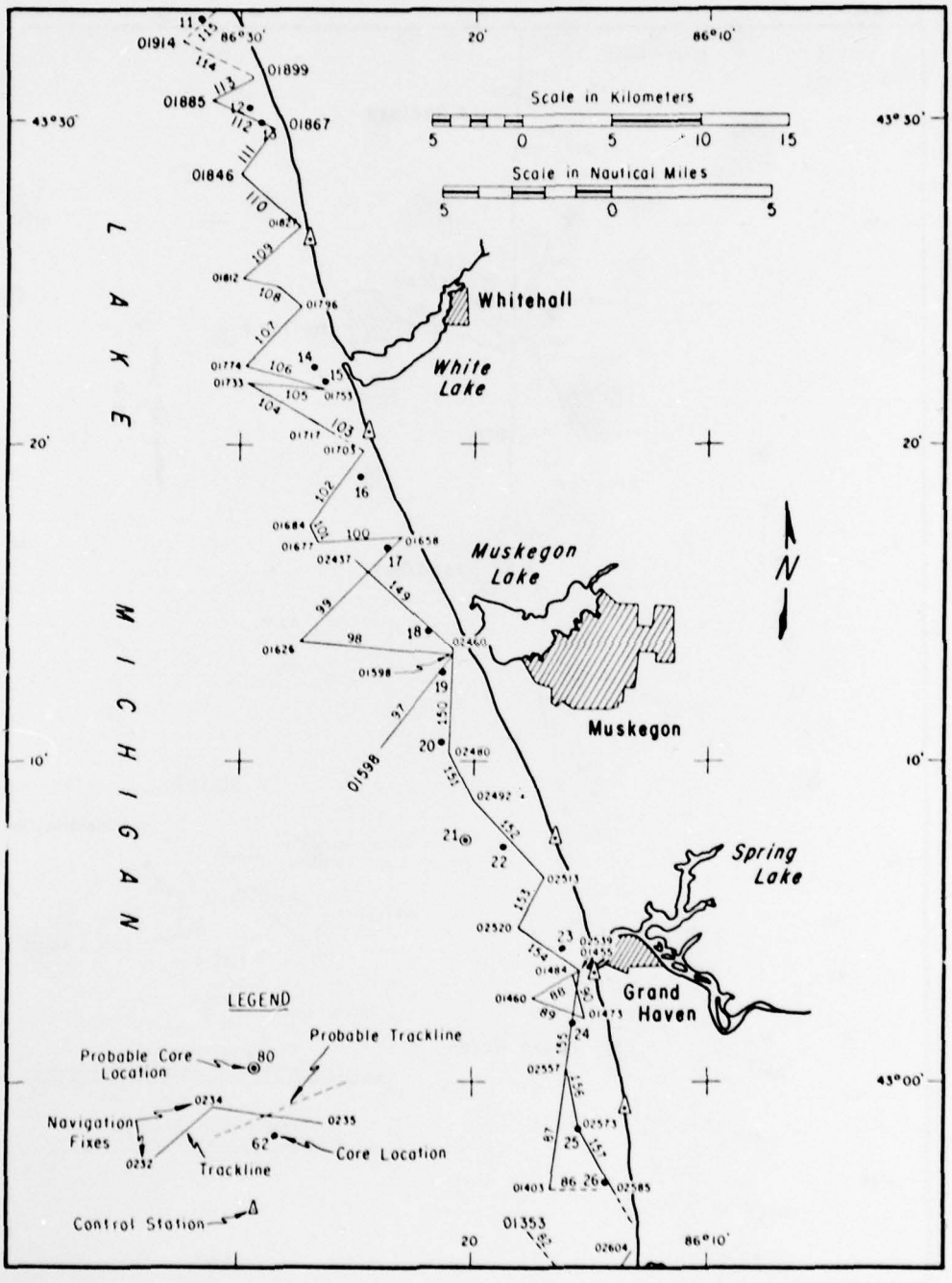


Figure 4. Survey coverage map 3 area.

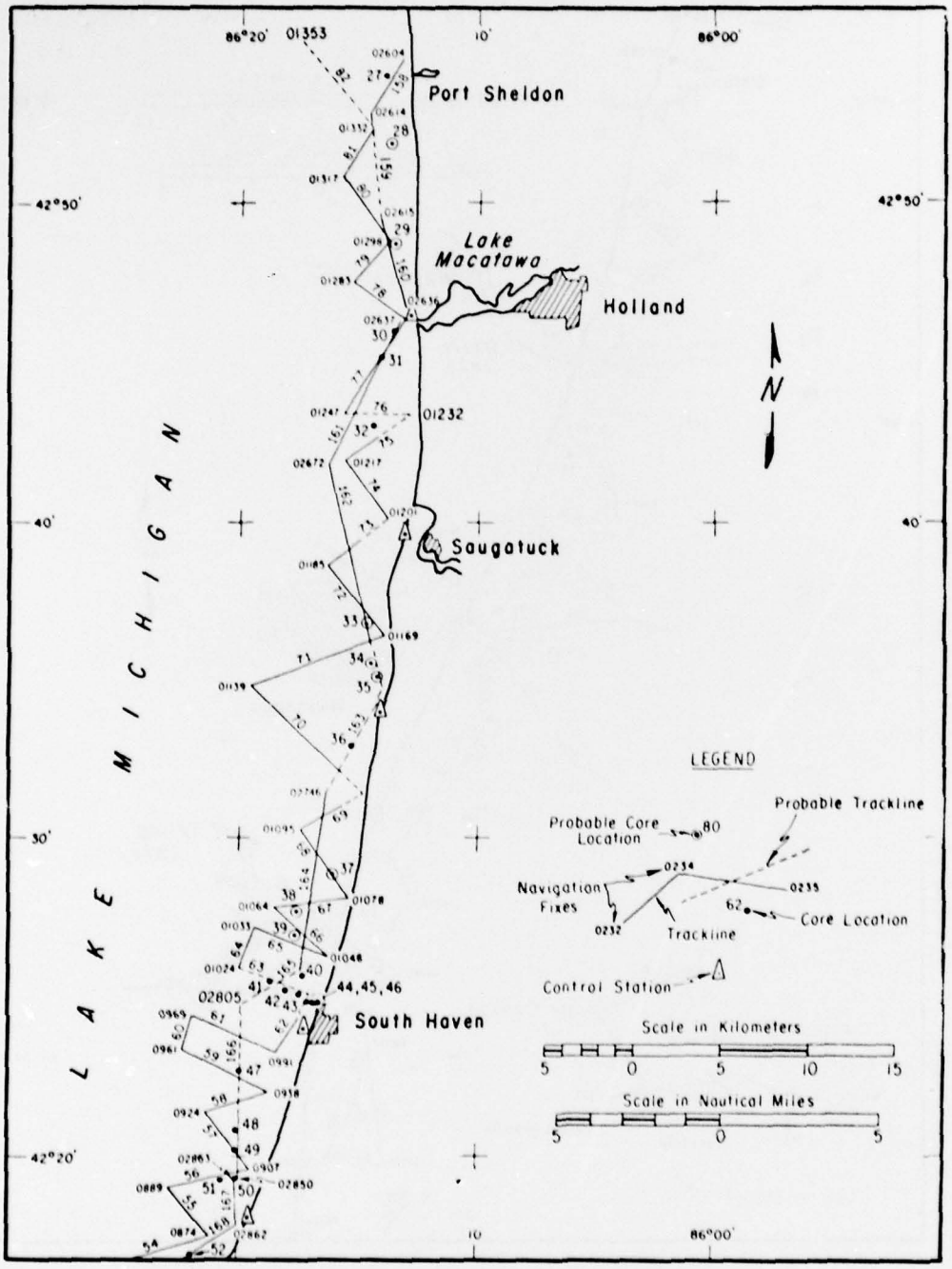


Figure 5. Survey coverage map 4 area.

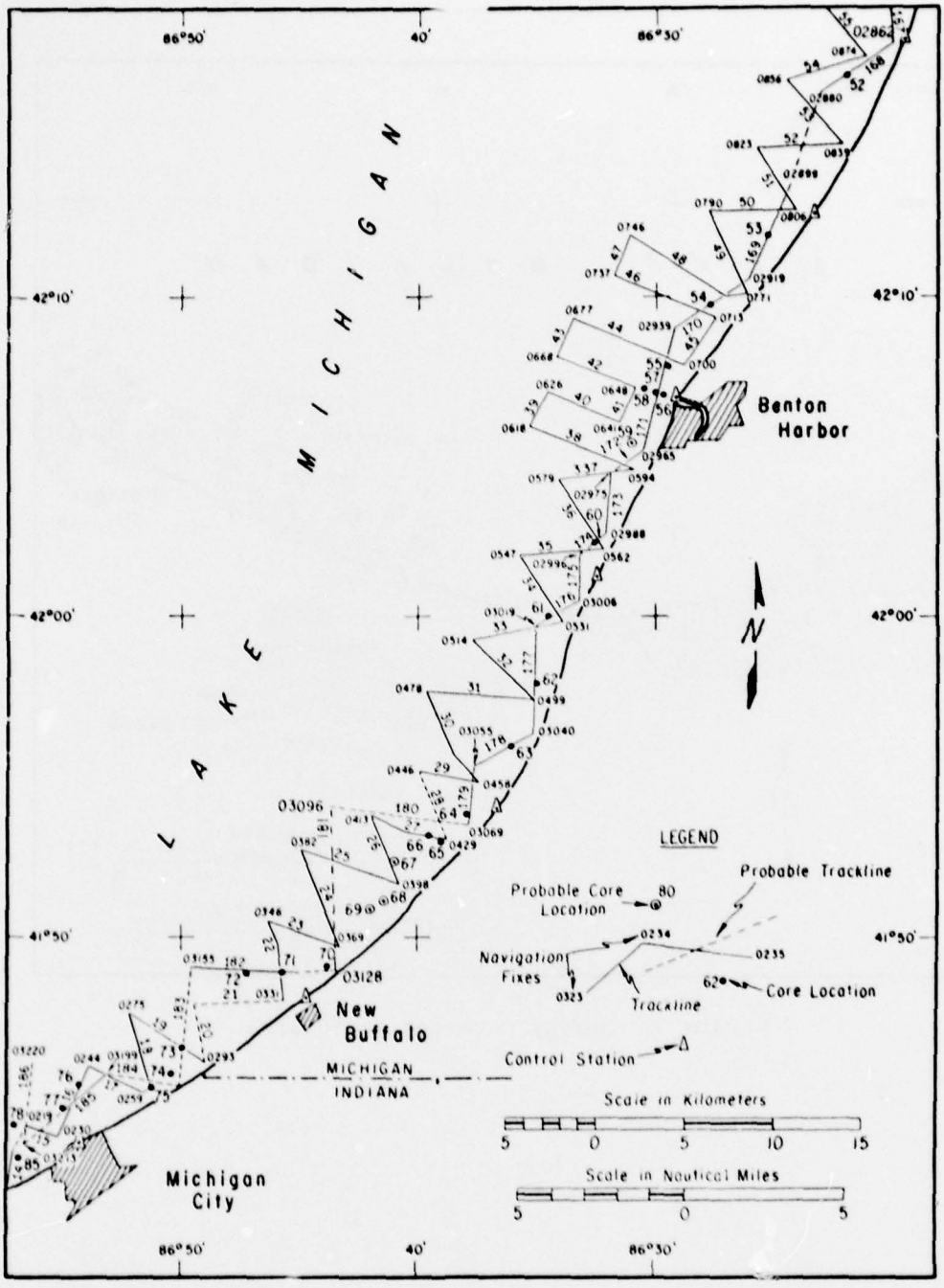


Figure 6. Survey coverage map 5 area.

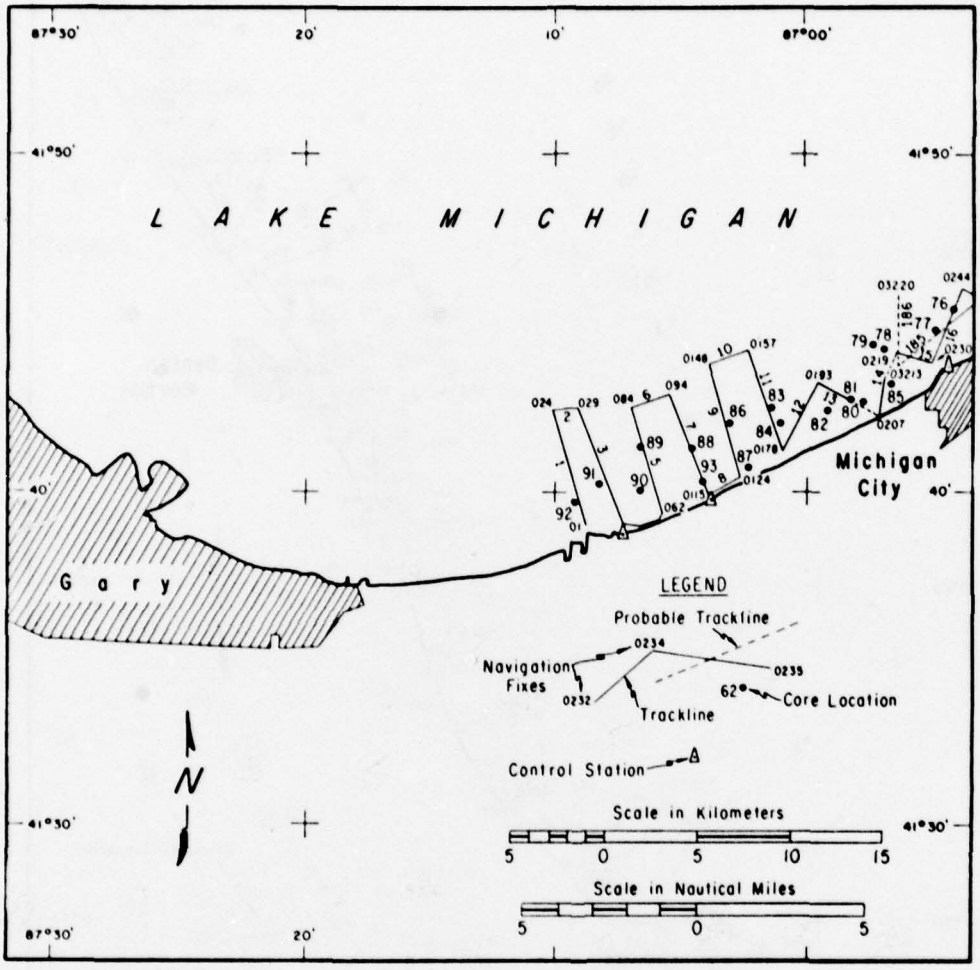


Figure 7. Survey coverage map 6 area.

kilohertz and 300 joules maximum power). The maximum depth below the lake floor where reflections are recorded on the boomer system which has the greater penetration potential, varies from 0 to more than 37 meters (120 feet). A "pinger" system achieved penetration of 0 to 15 meters (50 feet).

In addition to seismic reflection profiles run during the geophysical survey, a small pinger system (3.5 kilohertz; 25 joules) and side-scan sonar were used during the coring phase of the operation to record conditions in the immediate vicinity of each core site, and if time permitted, to run a continuous line between adjacent core sites. These data proved useful in assessing the bottom and very shallow subbottom conditions at core sites.

2. Core Boring.

After preliminary inspection of seismic reflection profiles, 93 core boring sites were selected. Cores at each of these sites were subsequently taken using a vibratory coring apparatus which obtains a nominal 8.9-centimeter-diameter (3.5 inches) core up to 6.1 meters (20 feet) in length at full penetration. After visual inspection, representative sediment samples were extracted from each core and grain-size distributions were measured by a rapid sediment analyzer (RSA) to determine the hydraulic diameter of particles by measuring their fall velocity in water (Stokes, 1966).[2] Lithologic descriptions of samples and core logs were also made by direct visual and microscopic examination of unit properties and constituent composition.

3. Navigation Control.

The position of the survey vessel and the coring platform was determined by a Mini Ranger II navigation system. This line-of-sight system provides continuous location data from two shore stations to a master station aboard the survey vessel. In general, fixes were obtained at [illegible] throughout the seismic reflection survey. [illegible] only [illegible] fixes are shown at the survey [illegible] in Figure [illegible].

[illegible]

[illegible]

feet). The accuracy of the position fixes using the dead-reckoning and one-range method is estimated to be ±1.8 kilometers (1 nautical mile) in the worst case.

III. RESULTS

1. Geologic Character of the Study Area.

a. Bottom Topography. Depths in the study area generally increase lakeward and at the lakeward limit of survey vary from about 18 to more than 61 meters (60 to 200 feet). The most prominent lake floor relief features were submarine ridges or bars which vary from subtle, low relief undulations to distinct ridges with relief up to 6.1 meters. These shore-parallel features occur throughout the study area but are most common in the northern half. Internal reflectors in some of the larger ridges indicate that their internal bedding consists of foreset series with accretion progressing in a lakeward direction (e.g., profile 9 in App. A). Cores indicate that most, if not all, of these ridges are composed of unconsolidated sand. Near Pentwater and in the Holland area (Fig. 1) the lake floor is roughened by sets of sand waves up to 1.5 meters (5 feet) high. These may be ephemeral features which reshape or shift position in response to prevailing hydrodynamic conditions; however, study data provide no evidence on this supposition. Other lake floor features consist mostly of aggregates of submarine hills and ridges which are highly irregular in distribution, shape, and relief. This topography suggests a relict glacial surface. Areas of smooth almost featureless lake floor occur interspersed with the topographically irregular areas throughout the study area.

b. Subbottom Structure. The seismic reflection profiles for this study reveal some elements of the shallow geological framework of southeastern Lake Michigan. Deeper features associated with pre-Pleistocene bedrock are generally below the depth of penetration of the seismic systems; however, it is the shallow reflectors that are most important in sand resources investigations and shallow reflector continuity is reasonably good throughout the study area. In general, the maximum depth of penetration and reflector continuity is greatest in the southern half of the area where acoustically transparent silt often occurs. Sand is dominant in the northern half except in offshore areas where thick segments of lake muds often underlie the bottom.

The absence of subbottom reflectors on the records or very shallow penetration may have been caused by the impenetrability of surficial or near-surficial deposits. Alternately, penetration may have been quite deep but the section penetrated was acoustically homogeneous and lacked suitable reflecting surfaces. Probably both factors are involved at different places. More powerful sound sources would reveal subbottom reflectors in the former case, but not in the latter case.

The interface between the first or surface sediment layer and underlying sediments is of particular interest in sand resource studies because

it often marks pronounced changes in lithology. If this interface produces a reflection, the thickness of the first layer can be determined directly from seismic reflection profiles. Where the first layer consists of suitable sand, available volumes can then be estimated. Where the first layer is unsuitable but overlies suitable deposits, the overburden thickness can be measured in the same manner.

A persistent reflector, believed in most places to mark the interface between the surficial layer and underlying deposits composed of different material, occurs in eastern Lake Michigan. This reflector (here called the *blue reflector*) was traced from line to line over a substantial part of the study area, but could not always be followed continuously. Gaps occur either because of poor record quality or insufficient acoustic contrast at the interface. The blue reflector is noted on the reduced profiles in Appendix A.

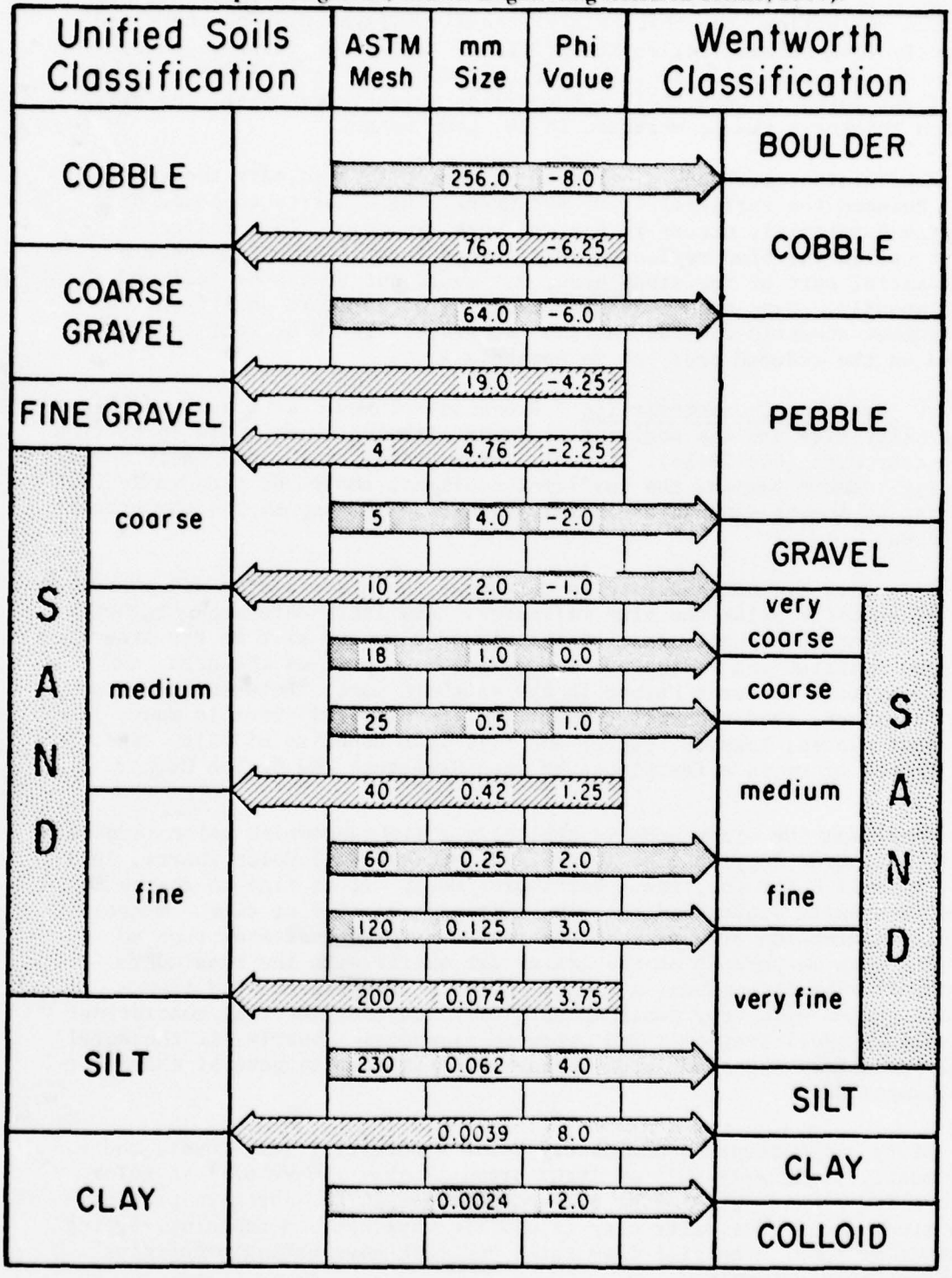
c. Sediment Characteristics. Brownish-colored quartz sand and light-gray silty clay are the dominant sediment lithologies found in cores from the study area (see Table). Gravel, sandy gravel, till, and shale occur locally. Where sampled the surficial sediments above the blue reflector consist of quartz sand which is fairly uniform in composition throughout the area.

Core data are not adequate to determine the distribution and character of deposits below the blue reflector. Available data suggest that these sediments probably consist chiefly of clay and silt in the area between Manistee and Pentwater, in the northern part of the area, and from Saugatuck to Burns Harbor in the southern part. Between Pentwater and Saugatuck, sand apparently underlies the blue reflector in many, if not most places; however, gravel and till-like deposits of silt, sand, and gravel occur in a few places between Saugatuck and Benton Harbor.

Sand from the study area is typically a light-brownish color (Munsell Soil Color Code 10 yr 5/3 to 10 yr 7/3) (Munsell Soil Color Charts, 1954 ed., Munsell Color Co., Inc., Baltimore, Md.). It is fine to coarse in size (Wentworth Scale) and contains little or no silt or clay. Microscopic examination of a few representative samples indicates that 80 to more than 90 percent of the grains are quartz with the remainder principally black opaques, and pale-yellow or reddish-colored translucent grains with very small amounts of calcareous material consisting of mollusk shell fragments and ostracod carapaces. Nearly all the surficial sands from the study area appear to be uniform in general character and composition.

Silty clays occur predominantly below a surficial sand cover, and are mostly light gray (N7) or light brownish gray (10 yr 6/1) in color with a few pinkish-gray (5 yr 6/2) occurrences in the northern part of the study area. The silty clay is plastic when wet and contains varying amounts of sand. The silt-clay ratio and bulk engineering properties have not been determined.

Table. Grain-size scales—soil classification (modified from U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977).



Additional sediment data in the form of core logs and granulometric characteristics are contained in Appendixes B and C.

2. Segment Description.

The study area is divided into 20 segments (for convenience of description), each of which is fairly uniform in bottom topography, subbottom reflector patterns, and sediment characteristics (Figs. 8 to 13). A brief segment-by-segment description of the geologic character of the area and assessment of the availability of offshore sand resources follows. High potential areas are designated in places where the sand deposits are judged to be of large volume, readily accessible, and with textural and minerological characteristics suitable for beach fill.

a. Segment 1. This segment is dominated by a large north-south trending linear shoal that fronts the northern part of the segment and merges with the shoreface in the southern half (profile 1, App. A). No cores were obtained from the segment; thus, the character of the sediment is uncertain. If the surficial layer contains suitable material, an analysis of the seismic data indicates that the thickest deposits probably occur along the western margin of the shoal near the north end of the segment.

b. Segment 2. Segment 2 includes Big Sable Point and peripheral areas to the north and south. Seismic records did not show subbottom reflectors in this area, suggesting the surficial layer is probably very thick off the main part of the point. In any case, dredging is not recommended off Big Sable Point because of the steep bottom slope and possible adverse effect on slope stability. The best prospects for obtaining sand are judged to be near the northern and southern ends of this segment where the bottom slopes are gentle and there are several ridges which may contain suitable sand. Cores 4 and 5 from the southern part of the segment contain clean, fine sand which is very uniform in size and character throughout the cores.

c. Segment 3. A smooth to jagged bottom topography prevails in segment 3 (profile 3, App. A). The blue reflector crops out or is only a few feet below the lake floor on all profiles; thus, the surficial layer appears to be thin and discontinuous. All of the cores taken in this segment (cores 1, 2, 3, 6, and 7) contain soft reddish-brown clay which either crops out or is thinly mantled by sand. The thickest sand layer occurs at the site of cores 1 and 2 where 0.6 and 1.8 meters (2 and 6 feet), respectively, of clean, medium sand overlies the clay layer. On the basis of present information the best area for further exploration in this segment is in the locale of cores 1 and 2.

d. Segment 4. The lake floor in this segment contains a number of broad smooth-surfaced ridges up to 3.0 meters (10 feet) high (profile 4, App. A). The blue reflector crops out or is very shallow in the swales between these ridges. The most promising locale for sand resources is in the southern part of the segment where the ridges have the greatest

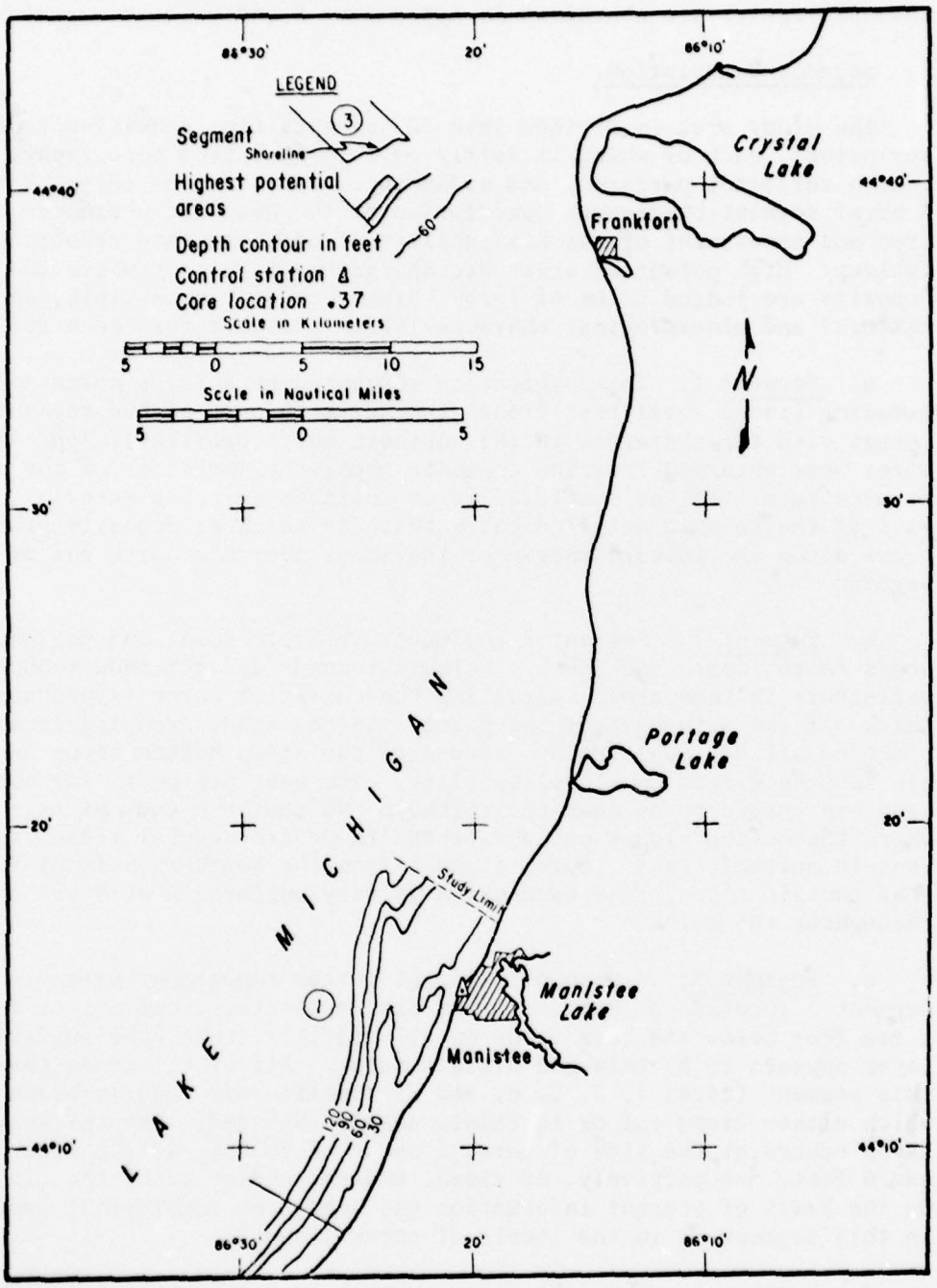


Figure 8. Bathymetry and sand potential, segment division 1, map 1 area.

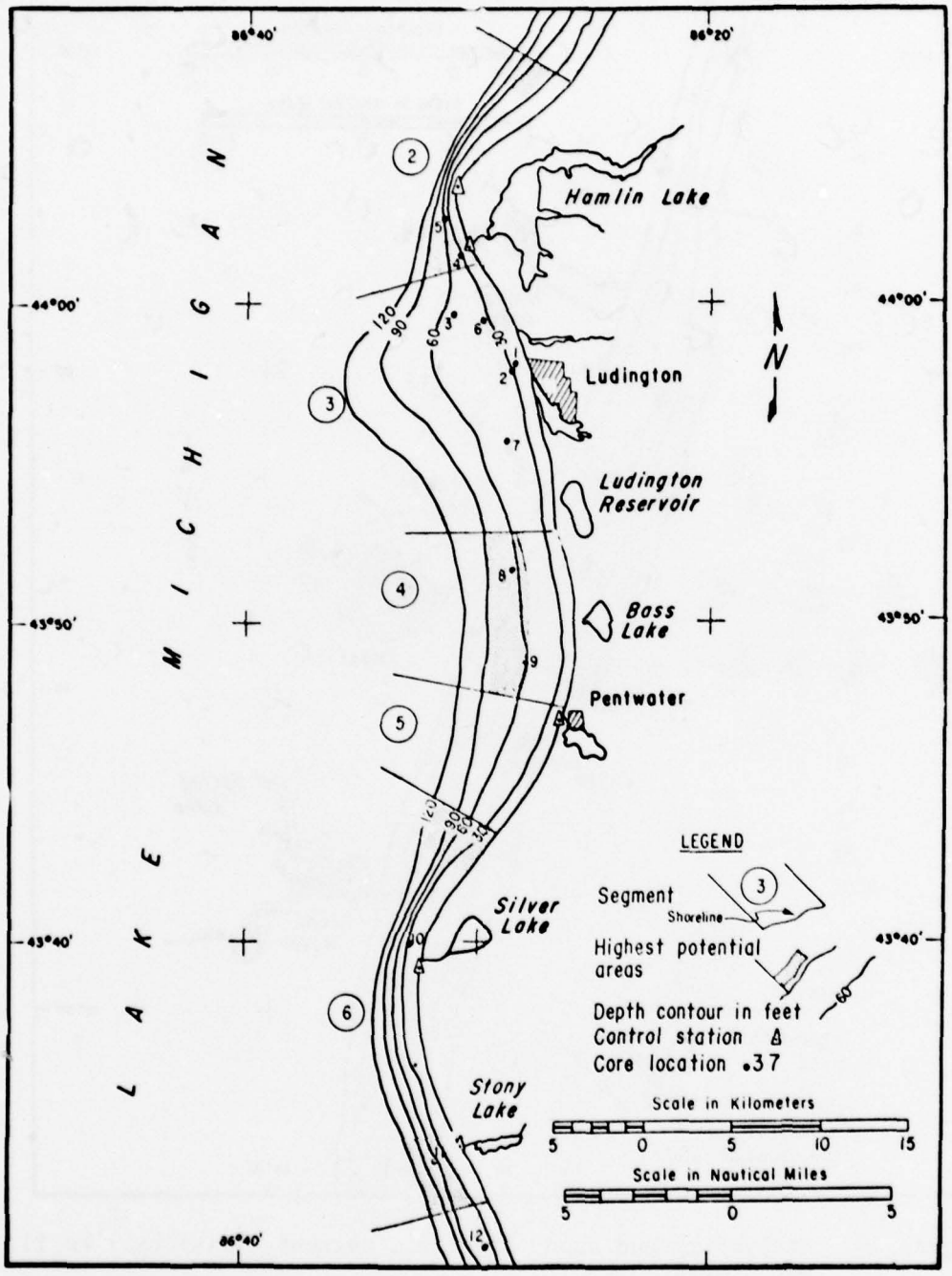


Figure 9. Bathymetry and sand potential, segment divisions 2 to 6, map 2 area.

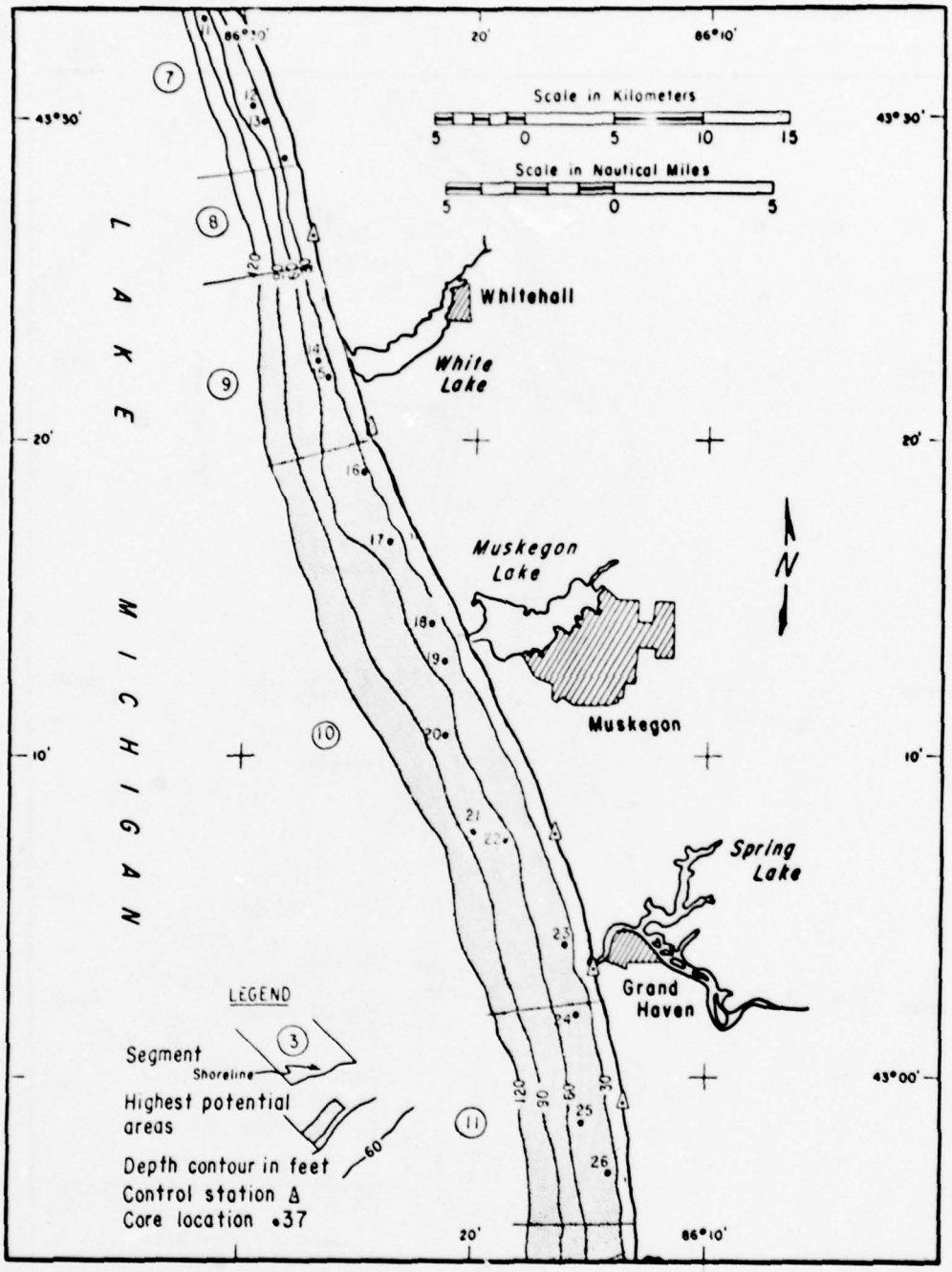


Figure 10. Bathymetry and sand potential, segment divisions 7 to 11, map 3 area.

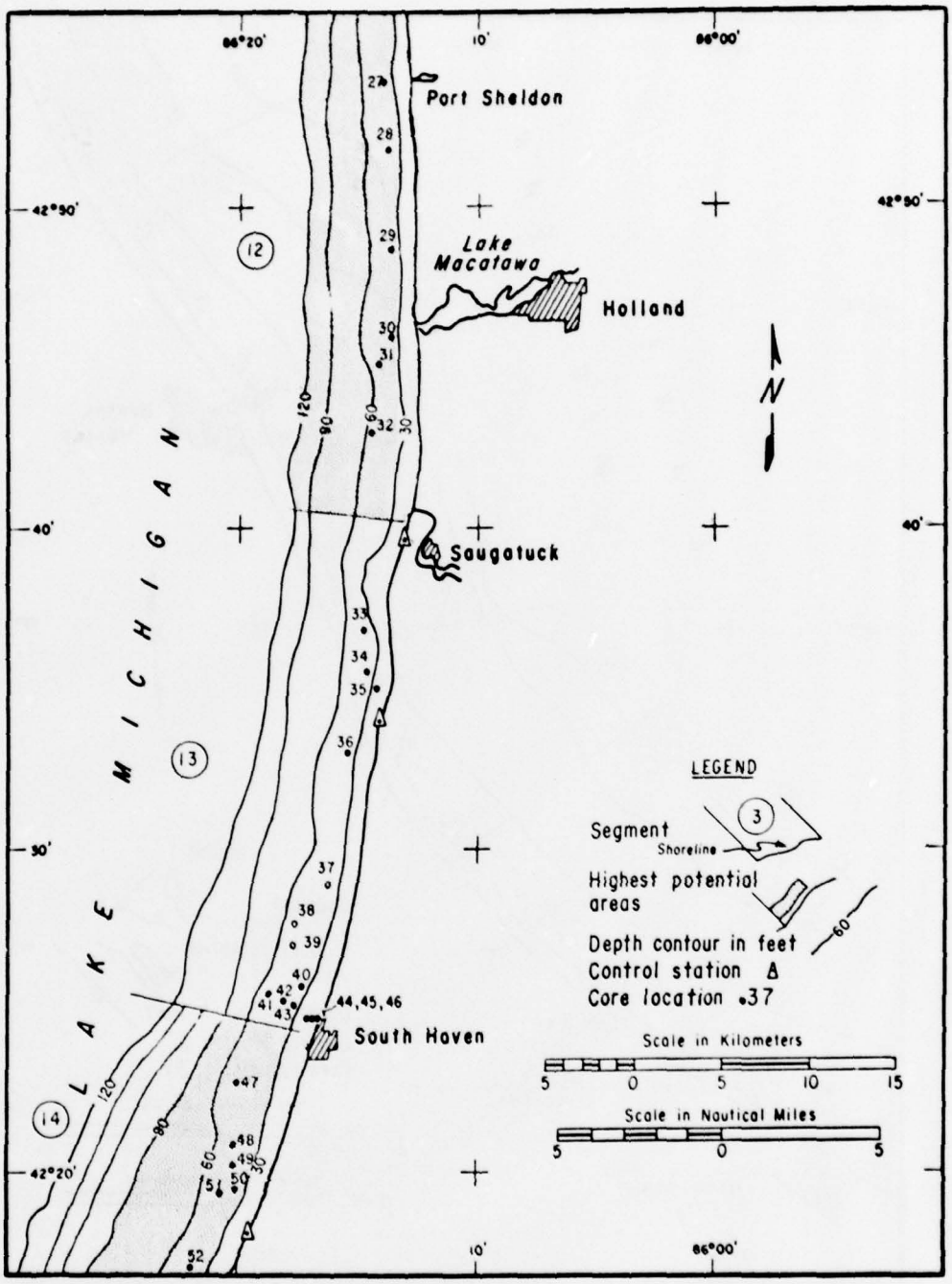


Figure 11. Bathymetry and sand potential, segment divisions 12, 13, and 14, map 4 area.

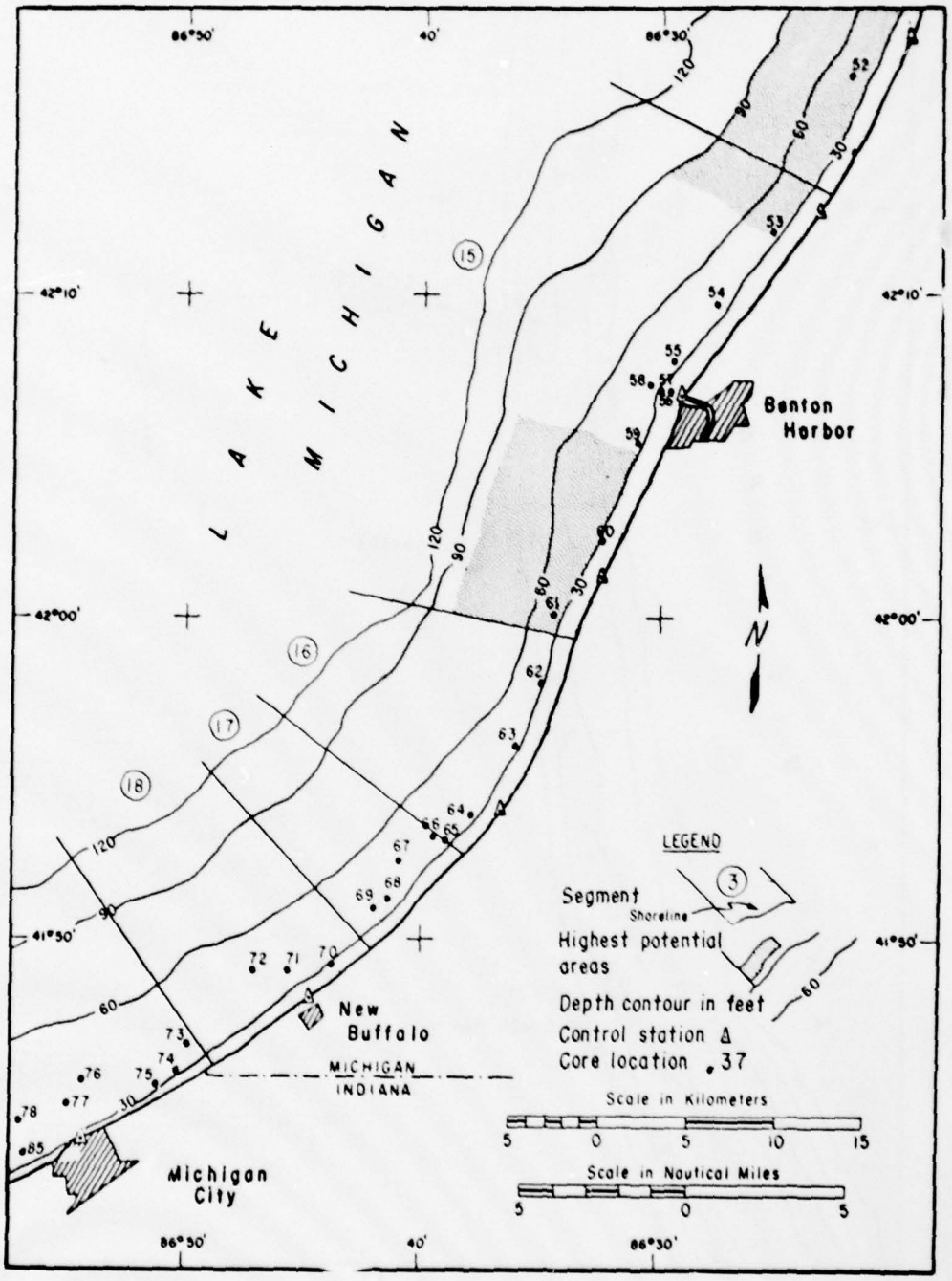


Figure 12. Bathymetry and sand potential, segment divisions 15 to 19, map 5 area.

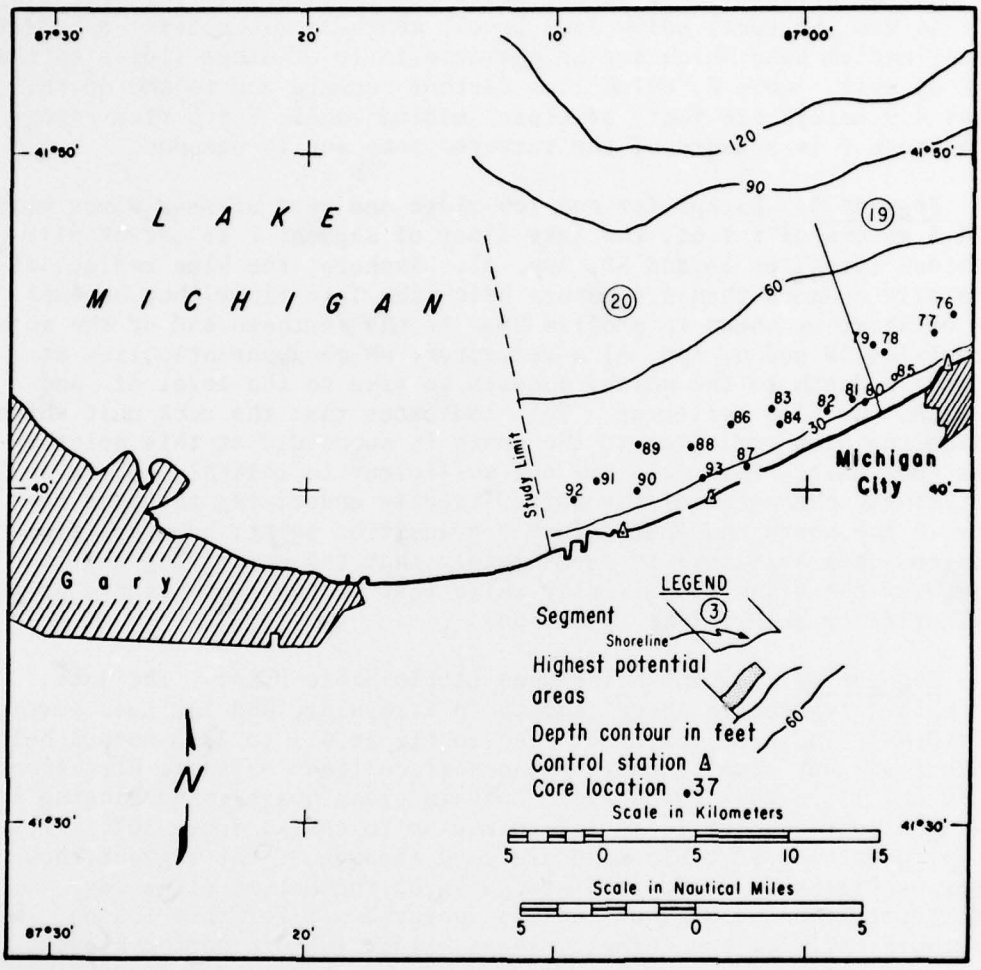


Figure 13. Bathymetry and sand potential, segment divisions 19 and 20, map 6 area.

relief and the surface layer is thickest. Core 9, from a ridge cresting at 16.8 meters (55 feet) below lake level, contains 2.6 meters (8.5 feet) of clean, medium sand which may be characteristic of other ridges in the segment as well. Core 8, which lies farther seaward and to the north, contains 4.9 meters (16 feet) of clean, medium sand. The bottom topography at core 8 is seaward of the surveyed zone and is unknown.

e. Segment 5. Except for one low ridge and sets of sand waves with up to 1.5 meters of relief, the lake floor of segment 5 is essentially featureless (profiles 5A and 5B, App. A). Inshore, the blue reflector is generally no more than 1.5 meters below the lake floor, but becomes deeper offshore as shown in profile 5B. At the southern end of the sector (profiles 5B and 6, App. A) a reflector, which apparently lies at considerable depth to the north, appears to rise to the level of, and merge with, the blue reflector. This indicates that the rock unit which underlies the blue reflector to the north is succeeded at this point by another rock unit. Core data are not sufficient to reliably determine the lithologic character of the units directly underlying the blue reflector to the north and south of this transition point; however, from the limited data available it seems likely that the underlying unit to the north of the transition is clay while that to the south is probably glacial drift or relict lake floor sand.

f. Segment 6. Segment 6 includes Little Sable Point. The lake floor in this segment is steep, smooth to irregular, and includes several large ridges. The blue reflector lies mostly at 6.1 to 18.3 meters below the lake floor but comes closer to the surface in an offshore direction. Cores 10 and 11 in the segment both contain clean quartz sand ranging in size from fine to medium (core 11) to medium to coarse (core 10). Prospects for obtaining suitable sand are good throughout the segment; however, as at Big Sable Point, the steepness of the bottom slope may dictate limitations on offshore borrow operations. For this reason the southern third of the segment, where milder inshore bottom slopes prevail, is considered the best area for potential offshore sand sources.

g. Segment 7. Segment 7 contains a series of ridges having 1.5 to 4.6 meters (5 to 15 feet) of relief. The blue reflector is shallow or crops out between the ridges but is buried as much as 6.1 meters beneath the ridge sediments. Cores 12 and 13 taken in this segment contain predominantly fine sand. Many ridges in this area may contain abundant sand; however, most lie in more than 18.3 meters of water.

h. Segment 8. This is a short segment of smooth lake bottom with a 3.1- to 6.1-meter accumulation of sediment above the blue reflector. No cores were taken in this segment; however, if the surf layer is sand, a large volume of material might be obtained in the area.

i. Segment 9. Bottom topography in segment 9 varies from smooth to irregular. Several large ridges of up to 6.1 meters relief occur seaward of the 15.2-meter (50 feet) isobath (profile 9, App. A). The blue reflector increases from less than 1.5 meters below the lake floor out to about

-16.8-meter (-55 feet) water depths, to more than 6.1 meters below lake floor farther offshore. Cores 14 and 15 from this segment contain clean, medium sand. Good prospects for sand borrow exist throughout the segment, especially lakeward of the 15.2-meter isobath.

j. Segment 10. The lake floor in this segment is mostly smooth but contains some low ridges (profile 10, App. A). The blue reflector appears to vary from 0 to about 4.6 meters below the lake floor. Eight cores from this segment (cores 16 to 23) contain clean, fine to medium sand indicating large quantities of suitable sand are distributed throughout the segment.

k. Segment 11. Several ridges with up to 3.1 meters relief occur in segment 11 (profile 11, App. A). The blue reflector is not evident inshore, but appears offshore where it crops out between the ridges. Cores 24, 25, and 26 from this segment contain 1.2 to 3.1 meters (4 to 10 feet) of clean, medium sand overlying fine sand. The best prospects for sand appear to be in the ridges.

l. Segment 12. The lake floor in this segment is predominantly smooth; however, it is interrupted by a series of sand waves with up to 1.5 meters of relief distributed throughout the segment (profile 12, App. A). The blue reflector is not apparent over most of this segment. Cores 27 to 32 contain clean, fine to medium sand. Core 30 also has a 0.6-meter layer of sandy pea gravel. There appears to be good potential for suitable sand in this segment.

m. Segment 13. A marked change in the character of the bottom and subbottom occurs in this segment. The lake floor is smooth to irregular with relief up to 3.1 meters. The topography is much less regular than in the ridge and swale areas to the north, and the lake floor along profiles 13A and 13B (App. A) has a jagged rather than smooth texture. Subbottom reflectors are fragmentary or missing in most of the segment; however, on line 164 the lake floor is underlain by a section of parallel, closely spaced reflectors that are somewhat distorted (profile 13A, App. A). Cores 33 to 46 from segment 13 are predominantly sand but gray clay and silt underlie the sand layer in seven cores. Gravel occurs in four cores. The surface sand layer is thickest (3.1 meters) at core 36 which is probably the best area for obtaining sand in segment 13. The gravelly sediments which occur in cores 33, 41, 42, and 44 are heterogenuous in size, mixed with sand and silt, and appear to be thin till deposits. The upper 0.6 meter in core 42 consists of clean, well-sorted granules and small pebbles. This deposit may be of value as construction aggregate.

n. Segment 14. In this segment the lake floor again becomes relatively regular and smooth but contains some ridges with up to 3.1 meters relief (profile 14A and 14B, App. A). The blue reflector is not apparent in most places and where evident it lies close to the lake floor. Cores 47 to 52 contain clean sand and the clay, silt, and gravel deposits occurring in segment 13 either do not extend into this area or were missed

by the cores. The thickest sand deposits are probably in the ridges of the northern part of the segment.

o. Segment 15. The lake floor in segment 15 is relatively smooth and featureless. Only a few short and discontinuous subbottom reflectors appear on profiles 15A and 15B (App. A). Cores 53 to 61 were obtained in this segment. Core 54 contains very fine gray sand. The remaining cores all contain fine to medium sand with layers of sandy granules and pebbles. In cores 58 to 59 the surficial sand layer is less than 1.2 meters thick and is underlain by gray silty clay and till. The best prospects for suitable sand are near the north end and the southern third of the segment.

p. Segment 16. In segment 16 the lake floor is also relatively smooth and featureless (profile 16, App. A). The blue reflector appears to be at or very near the surface in most places. A deeper reflector which rises to the lake floor on this segment is probably the top of a shale unit cored in segment 17. All but one core from this segment (cores 62 to 66) contain a thin sand layer less than 0.5 meter (1.5 feet) thick overlying gray clay. In core 64 the sand layer is 1.7 meters (5.5 feet) thick and the locale of this core site is probably the best area for potential sand borrow. Elsewhere, prospects for obtaining large volumes of sand appear to be poor.

q. Segment 17. The dominant feature of segment 17 is a low mound with an extremely jagged surface characterized by a shale outcrop. The surface of the shale creates a strong subbottom reflector in places peripheral to the outcrop where it is buried beneath younger sediments (profile 17, App. A). All three cores (cores 67, 68, and 69) from this segment were in the shale outcrop area. None penetrated more than 0.5 meter into this highly resistant material. Little or no sand occurs in the shale outcrop area, but sand deposits may exist around the periphery.

r. Segment 18. A series of low ridges 1.5 to 3.1 meters high characterize the lake floor in this segment (profile 18, App. A). The blue reflector crops out between the ridges, but lies up to 3.1 meters beneath the ridge areas and is occasionally incised by 4.6-meter-deep channellike depressions (profile 18, App. A). Cores 70 to 73 were obtained in this segment. Core 73 contains only sand; the remaining cores contain sand overlying gray silt and clay. Limited quantities of clean sand can probably be obtained from the ridge areas. The cleanest and coarsest sand occurs in core 73 from the southern part of the segment.

s. Segment 19. The bottom topography in this segment varies from no relief to low undulating ridges and swales of about 1.5 meters relief. The blue reflector crops out in most places but may lie as much as 2.4 meters (8 feet) below some of the ridges. Cores 74 to 79 and core 85 contain mostly gray clay and silt with a surficial sand layer of 0.6 meter or less in thickness. Prospects for recovering large quantities of sand in this segment are poor. The best places for further investigation are the ridge areas in the southern part of the segment.

t. Segment 20. The lake floor in segment 20 is smooth to slightly undulating with low ridges up to 1.5 meters high. The blue reflector crops out throughout most of the area. Cores 81 to 93 were taken in this segment. With one exception, these cores contain a predominance of gray silt and clay covered by a thin sand veneer less than 0.6 meter thick. Core 91 contains a 1.2-meter layer of fine to very fine sand overlying the clay. A thin layer of gravel occurs at the top of cores 81 and 83, and a 0.3-meter (1 foot) layer of granules occurs at -1 meter (-3 feet) in core 84. In general, prospects for obtaining sand or gravel in quantity from this segment are poor. Some low, broad ridges which occur in the northern part of the segment are probably the best sites for further exploration.

IV. SUMMARY

The eastern shore of Lake Michigan between Manistee, Michigan, and Burns Harbor, Indiana, was surveyed to locate offshore sand deposits suitable for use in beach restoration and maintenance. Survey data consist of seismic reflection profiles along 915 kilometers (569 miles) of trackline and 93 cores up to 6.1 meters (20 feet) long. These data were from water depths ranging from about 3.7 to 37.0 meters (12 to 120 feet).

The predominant sediment types occurring in the study area are clean, fine to coarse quartz sand and silty clay. Sand is the characteristic surficial deposit. Silty clay is most characteristic of the shallow subbottom deposits. Clay, gravel, and till-like mixtures of silt, sand, pebbles, and cobbles occur locally. Shale occurs in one small area near New Buffalo, Michigan.

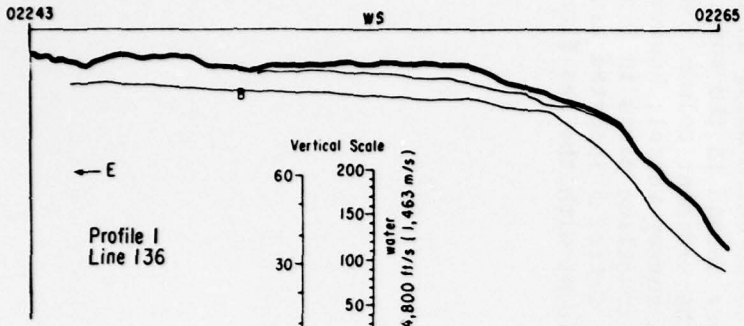
The best potential for offshore sand resources is in the area between Whitehall and Saugatuck, Michigan. Localized deposits with good potential occur in several places between Manistee and Whitehall, Michigan, and from Saugatuck to 15 kilometers (9.3 miles) south of Benton Harbor, Michigan. The area of lowest potential is that from Benton Harbor southward to Burns Harbor, Indiana, where only a thin veneer of surficial sand overlies silt and clay deposits.

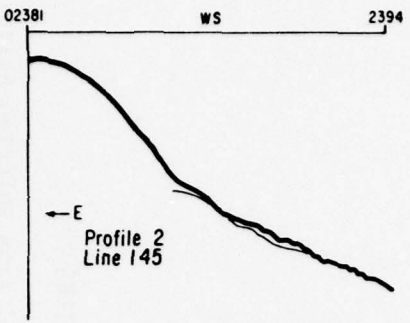
APPENDIX A

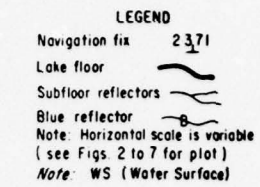
SEISMIC REFLECTION PROFILES

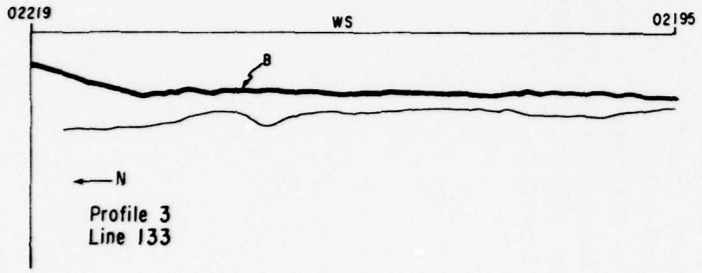
Appendix A contains line profiles prepared from selected seismic reflection records of the study area. Profile numbers are those assigned to the coastal segment which they represent. Line locations are shown in Figures 2 to 7. The vertical scales were constructed using an assumed sound velocity of 1,463 meters (4,800 feet) per second in the water column and 1,658 meters (5,440 feet) per second in the sediment column. Horizontal scales vary according to the speed of the survey vessel; however, line lengths can be estimated by reference to the trackline plots in Figures 2 to 7. The blue reflector is indicated by the letter B inserted along the reflector line (where the reflector is coincident with the sea floor, the B is inserted on the sea floor line).

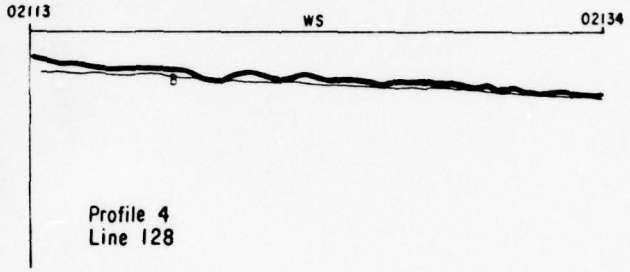
PRECEDING PAGE BLANK

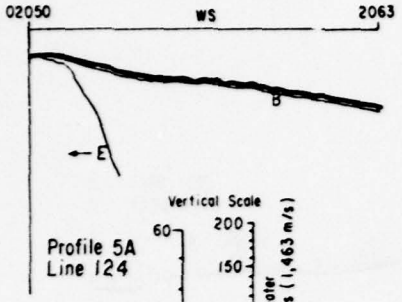

02243
WS
02265
B
Vertical Scale
E
Profile 1
Line 136
60
30
0
30
60
meters
200
150
100
50
0
50
100
150
200
feet
water
4,800 ft/s (1,463 m/s)
sediment
5,440 ft/s (1,658 m/s)


02381
WS
2394
E
Profile 2
Line 145

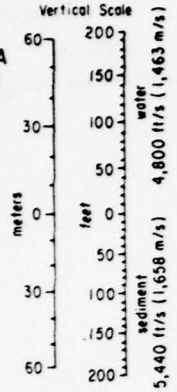

LEGEND
Navigation fix
23 71
Lake floor
Subfloor reflectors
Blue reflector
B
Note: Horizontal scale is variable
(see Figs. 2 to 7 for plot)
Note: WS (Water Surface)

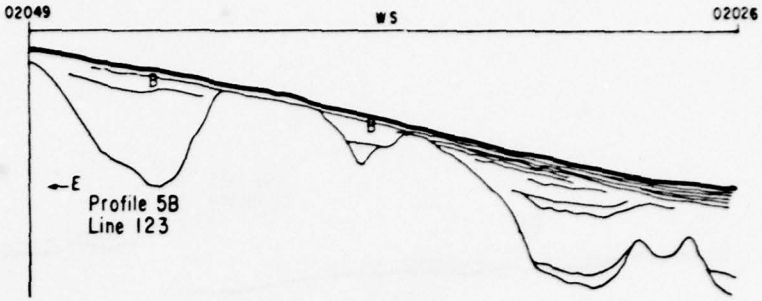

02219
WS
02195
B
N
Profile 3
Line 133


02113
WS
02134
B
Profile 4
Line 128



Profile 5A
Line 124





Profile 5B
Line 123

LEGEND

Navigation fix 2371

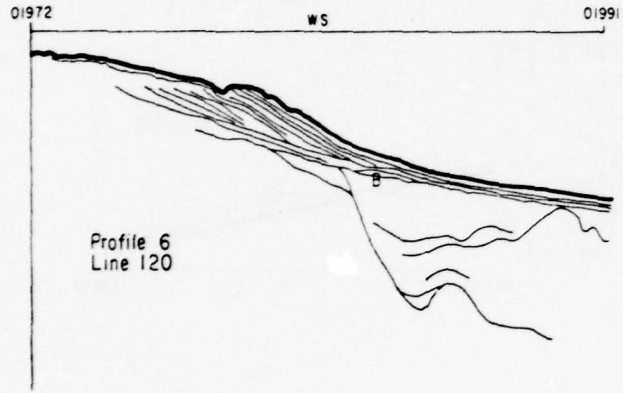
Lake floor

Subfloor reflectors

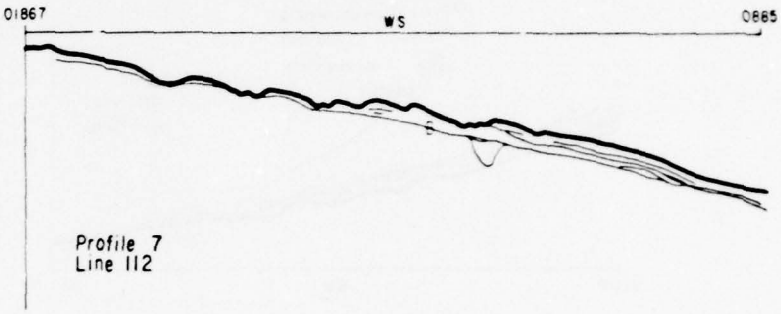
Blue reflector B

Note Horizontal scale is variable
(see Figs 2 to 7 for plot)

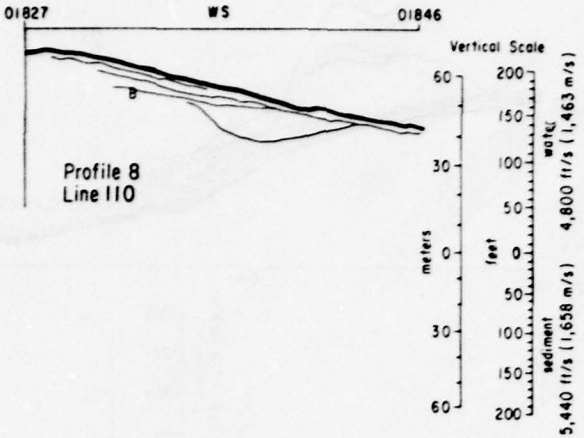
Note WS (Water Surface)

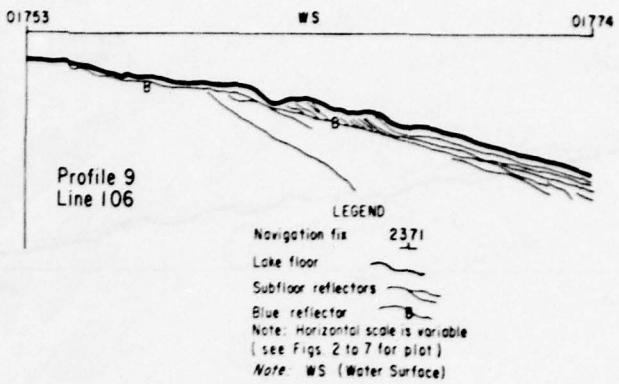


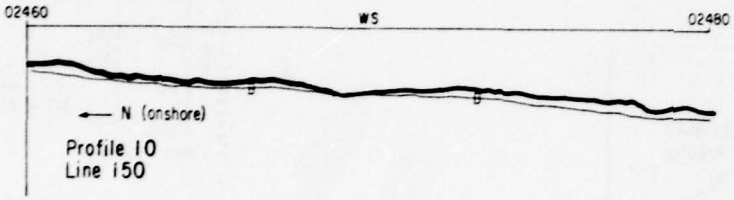
Profile 6
Line 120

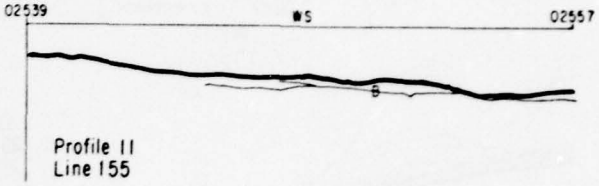


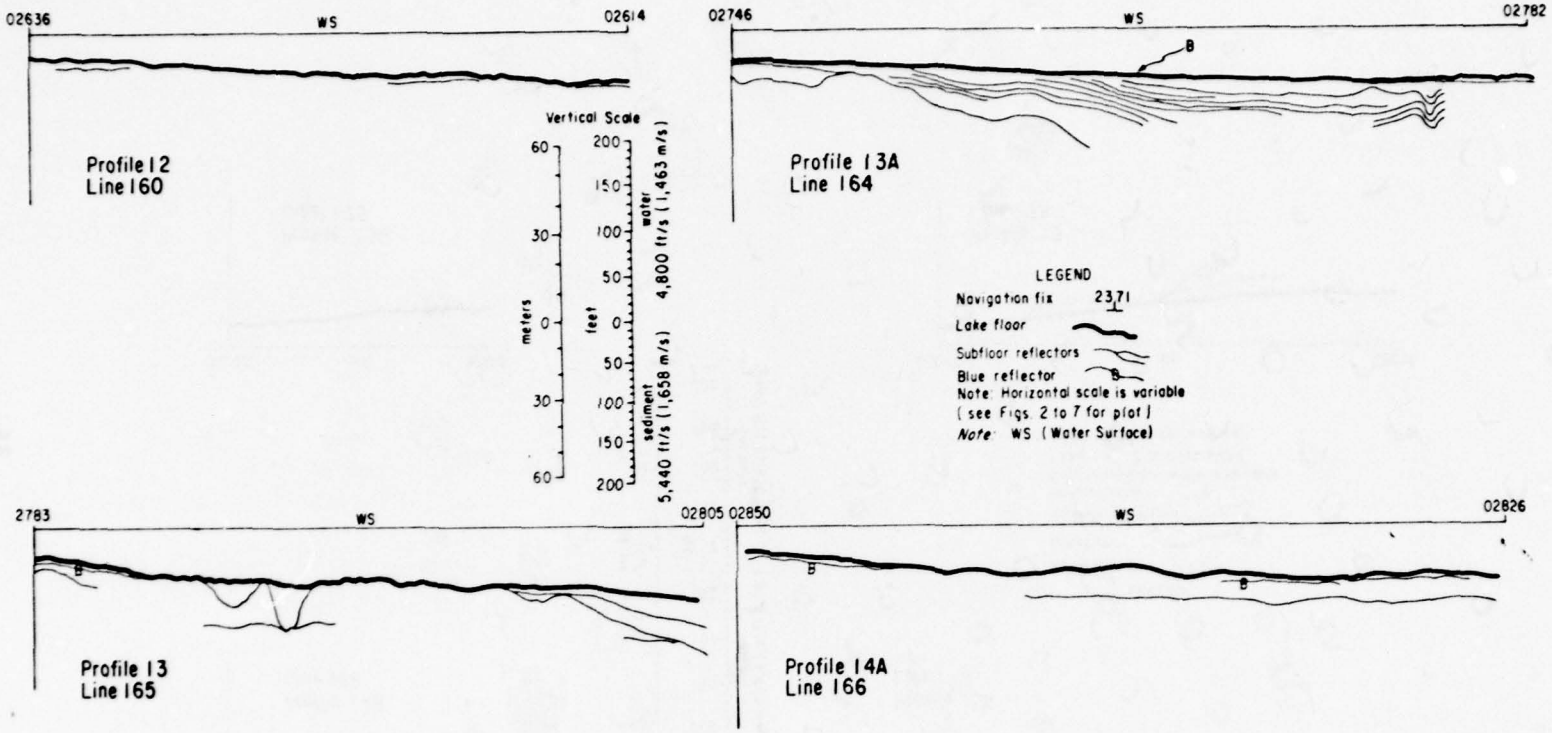
Profile 7
Line 112

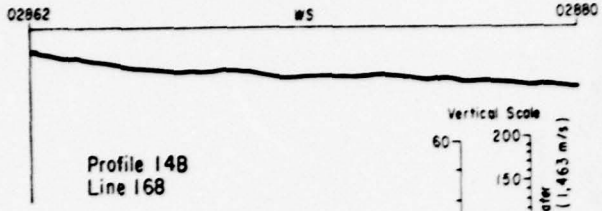

01827
WS
01846
Vertical Scale
meters
feet
water
4,800 ft/s (1,463 m/s)
sediment
5,440 ft/s (1,658 m/s)
B
Profile 8
Line 110


01753
WS
01774
B
Profile 9
Line 106
LEGEND
Navigation fix
2371
Lake floor
Subfloor reflectors
Blue reflector
B
Note: Horizontal scale is variable
(see Figs. 2 to 7 for plot)
Note: WS (Water Surface)

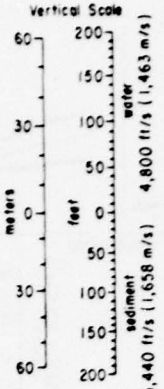

02460
WS
02480
N (onshore)
B
Profile 10
Line 150

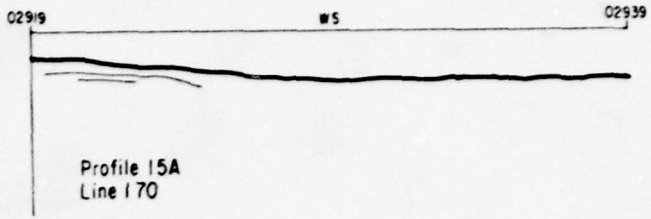

02539
WS
02557
B
Profile 11
Line 155


02636
WS
02614
Profile 12
Line 160
Vertical Scale
meters
feet
water
4,800 ft/s (1,463 m/s)
sediment
5,440 ft/s (1,658 m/s)
02746
WS
02782
B
Profile 13A
Line 164
LEGEND
Navigation fix 23,71
Lake floor
Subfloor reflectors
Blue reflector B
Note: Horizontal scale is variable
(see Figs. 2 to 7 for plot)
Note: WS (Water Surface)
2783
WS
02805
02850
B
Profile 13
Line 165
WS
02826
B
B
Profile 14A
Line 166

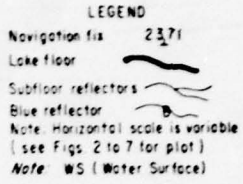


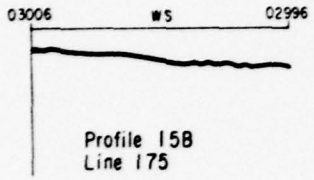
Profile 14B
Line 168



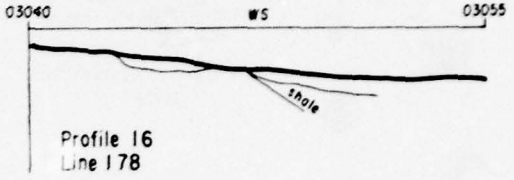


Profile 15A
Line 170

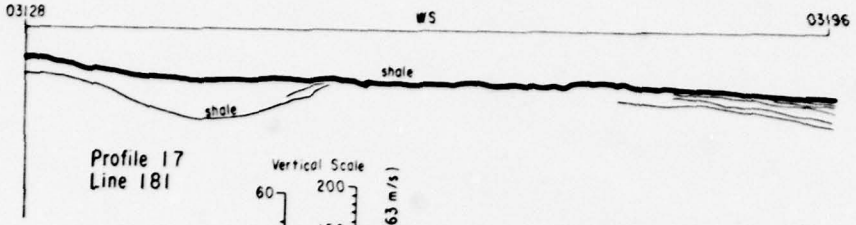




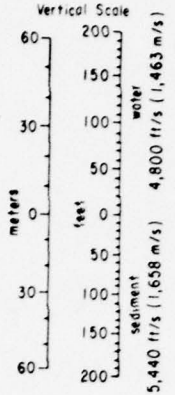
Profile 15B
Line 175

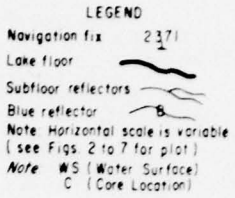


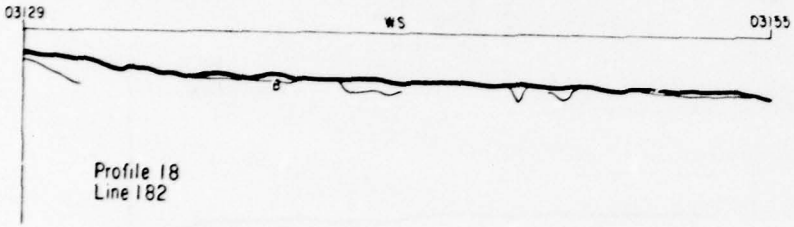
Profile 16
Line 178



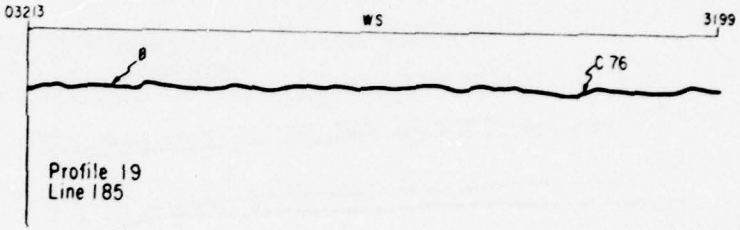
Profile 17
Line 181



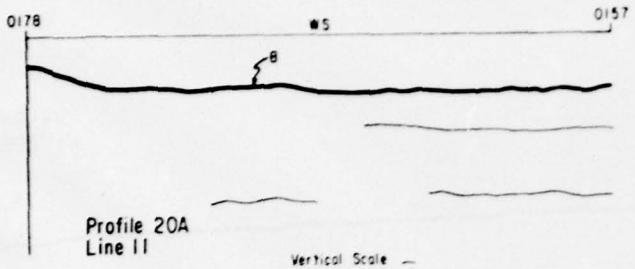




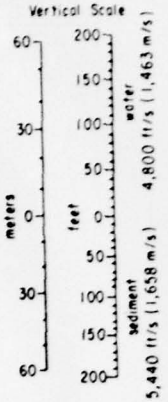
Profile 18
Line 182

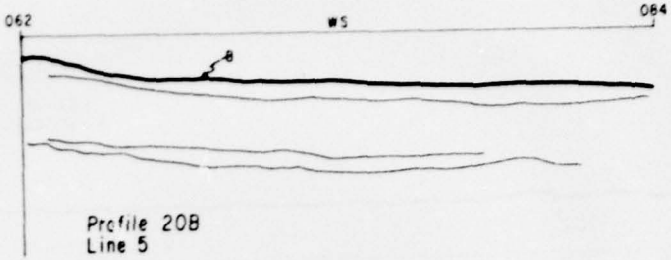


Profile 19
Line 185



Profile 20A
Line 11





Profile 20B
Line 5

LEGEND

Navigation fix 23,71

Lake floor

Subfloor reflectors

Blue reflector B

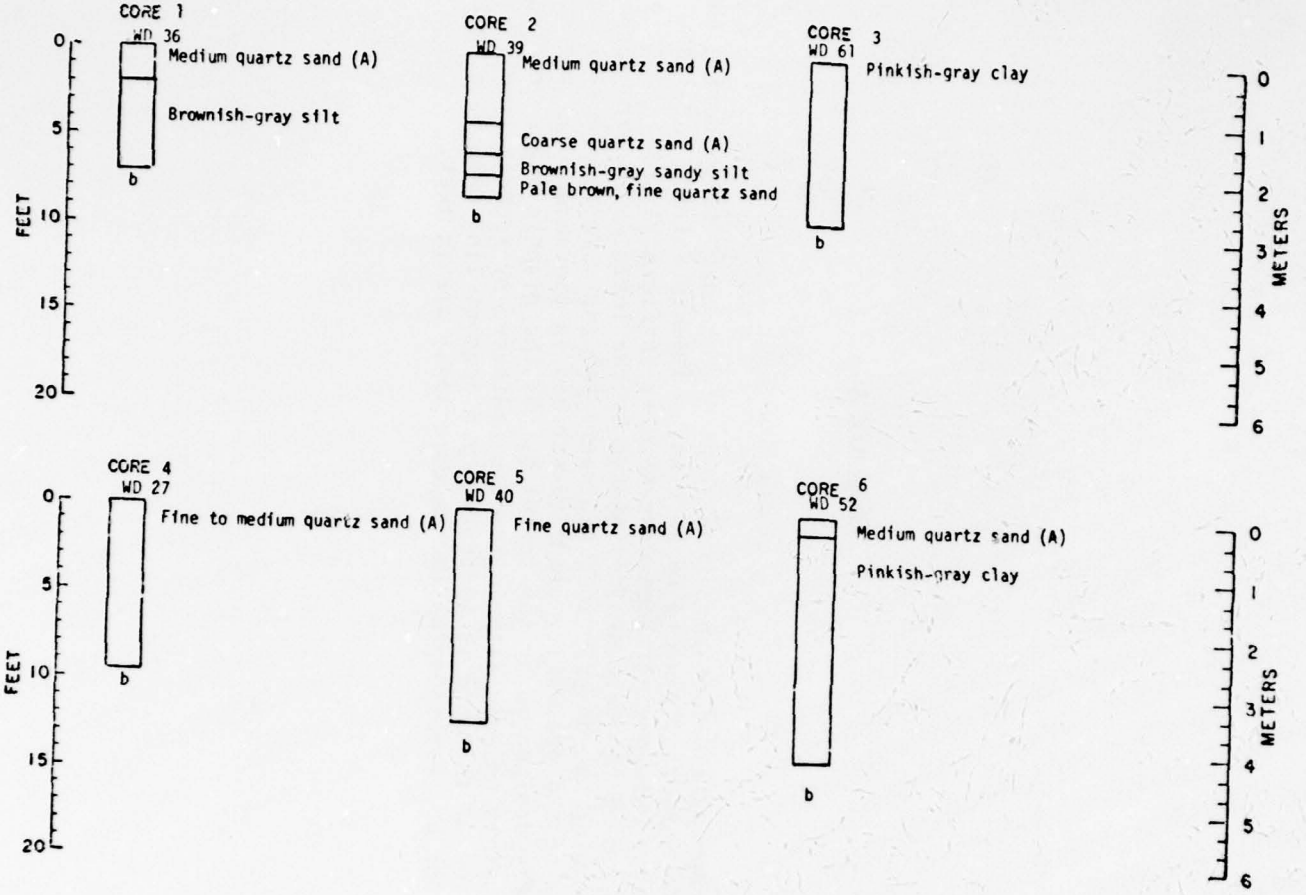
Note Horizontal scale is variable (see Figs 2 to 7 for plot)

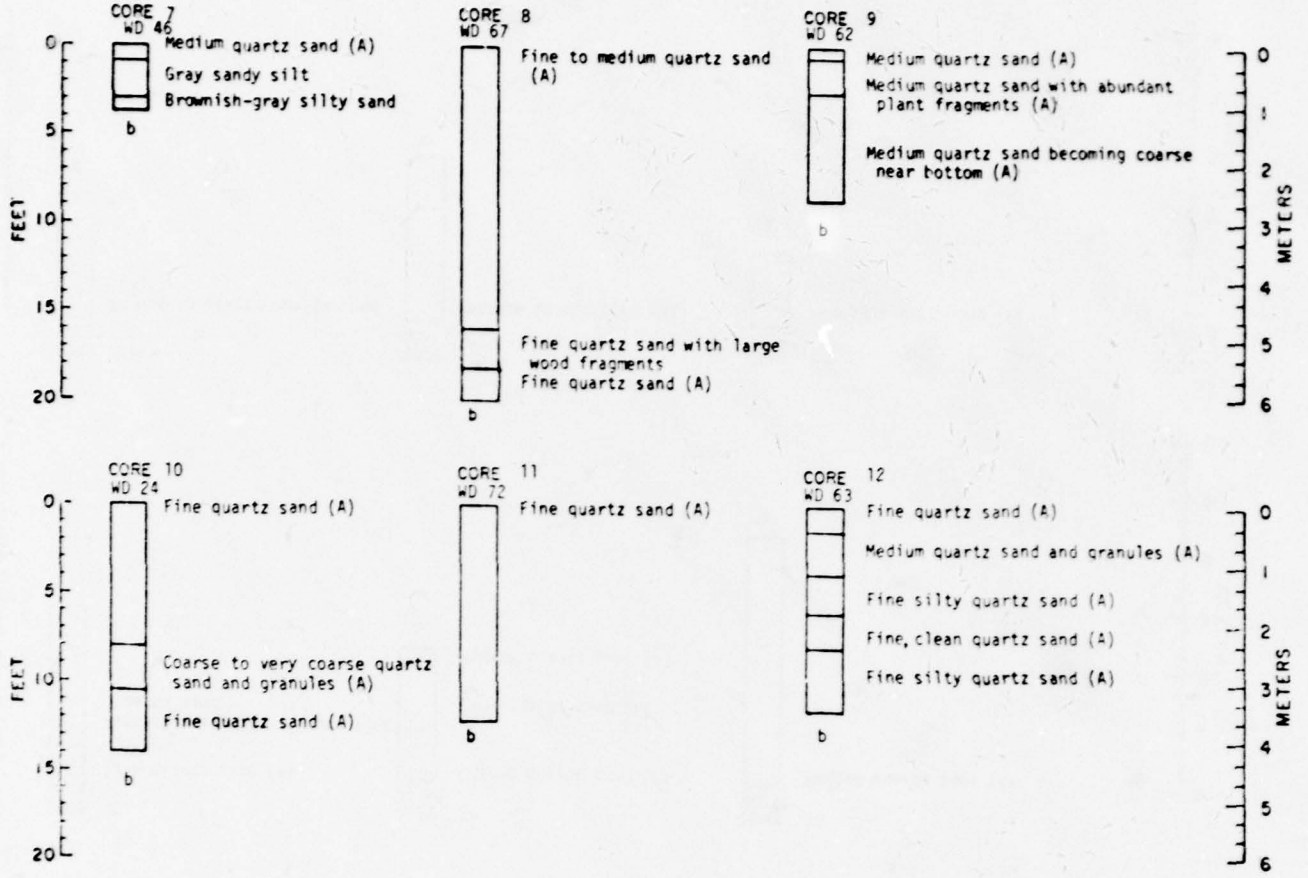
Note WS (Water Surface)

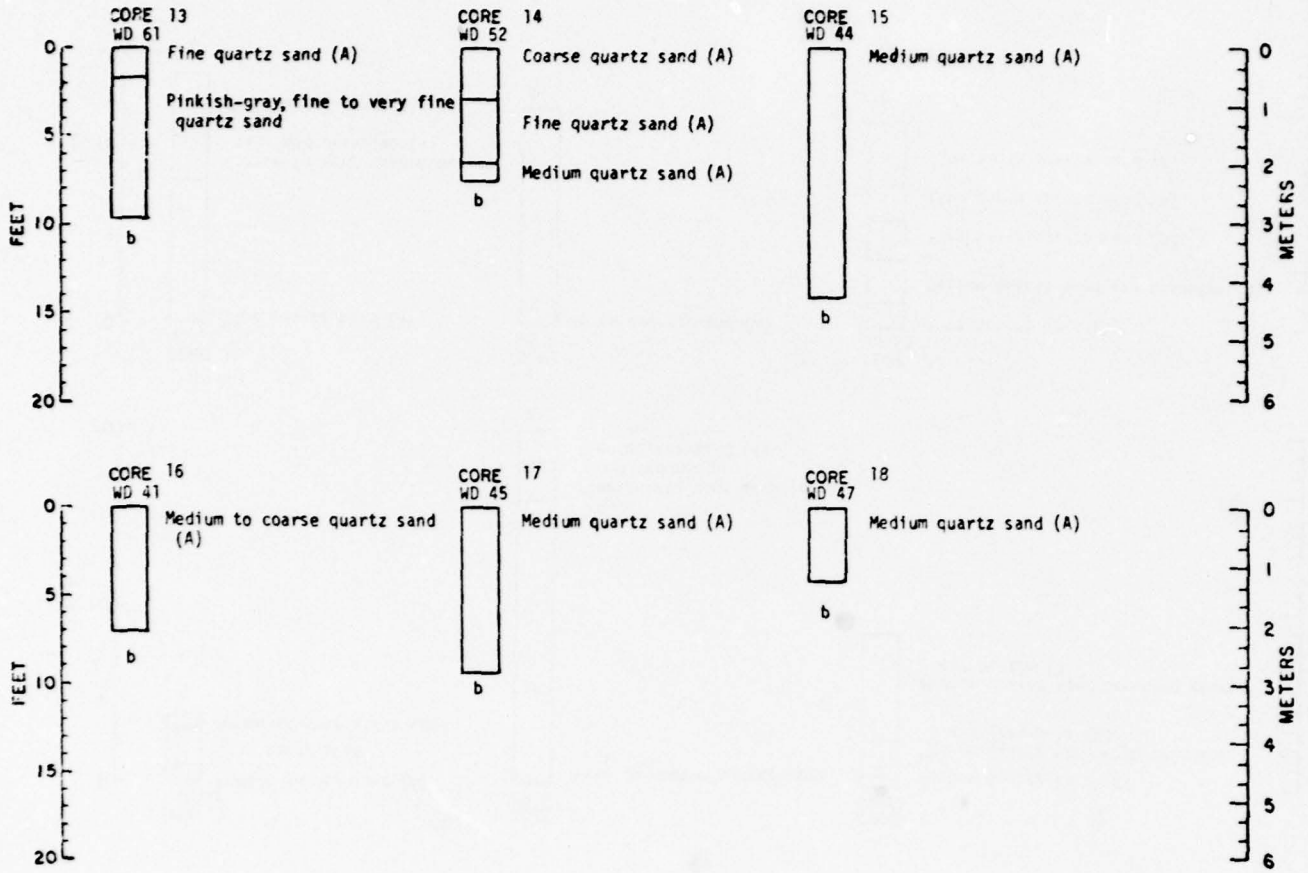
APPENDIX B

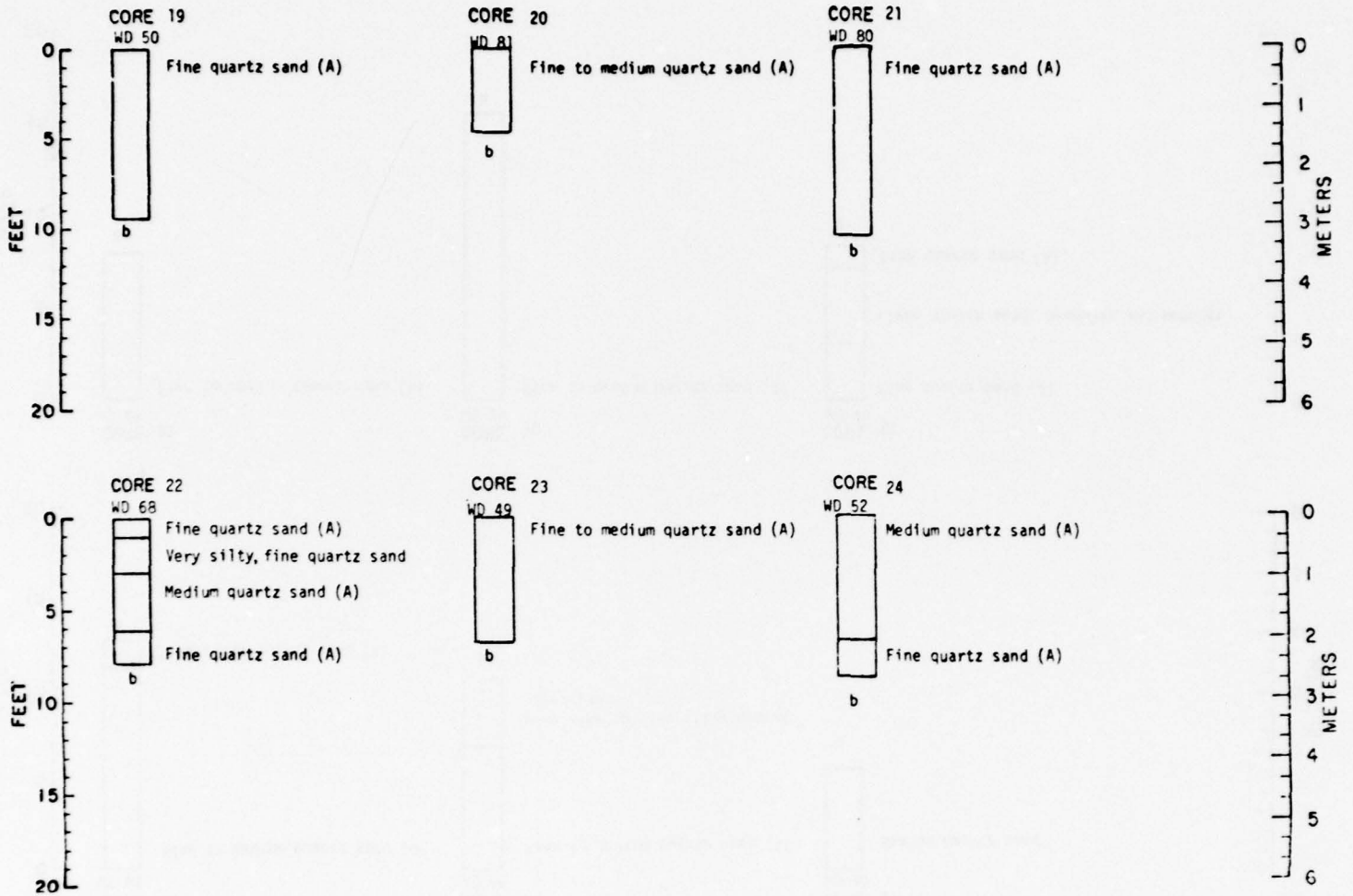
CORE LOGS

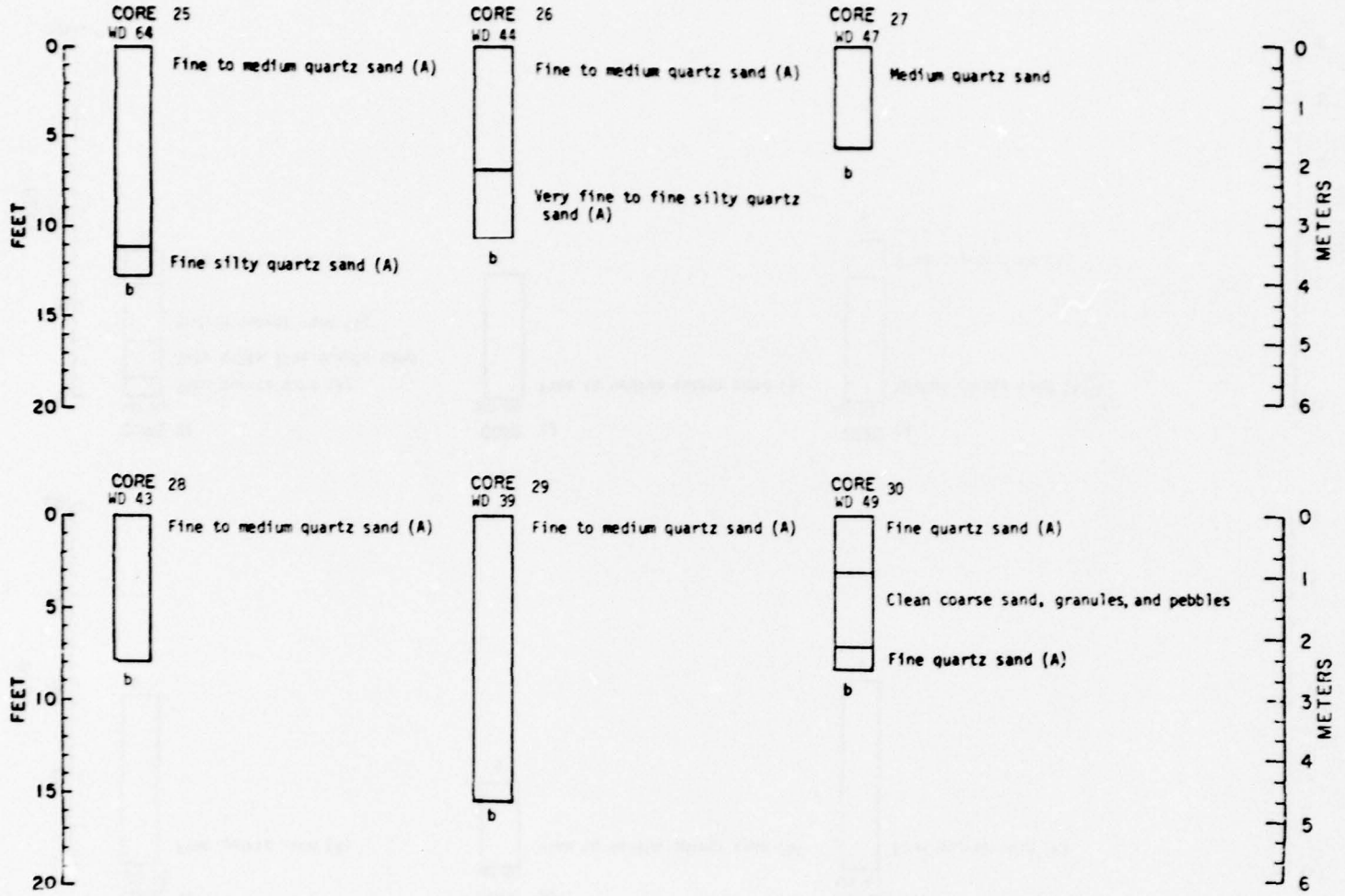
Appendix B contains visual logs of the cores taken during the ICONS survey. To avoid repetition, sediments falling into the general category of those described as surficial sands in Section III,1,c of the text are designated by the letter A in parentheses following the description; sediments falling into the general category of the gray silty clays (described in the same Sec.) are similarly designated by the letter B. On the graphic logs, vertical divisions between lithologies are indicated by segment lines. The bottom of the core is indicated by a segment line underlain by the letter b. Water depths (WD on core logs) are in feet.

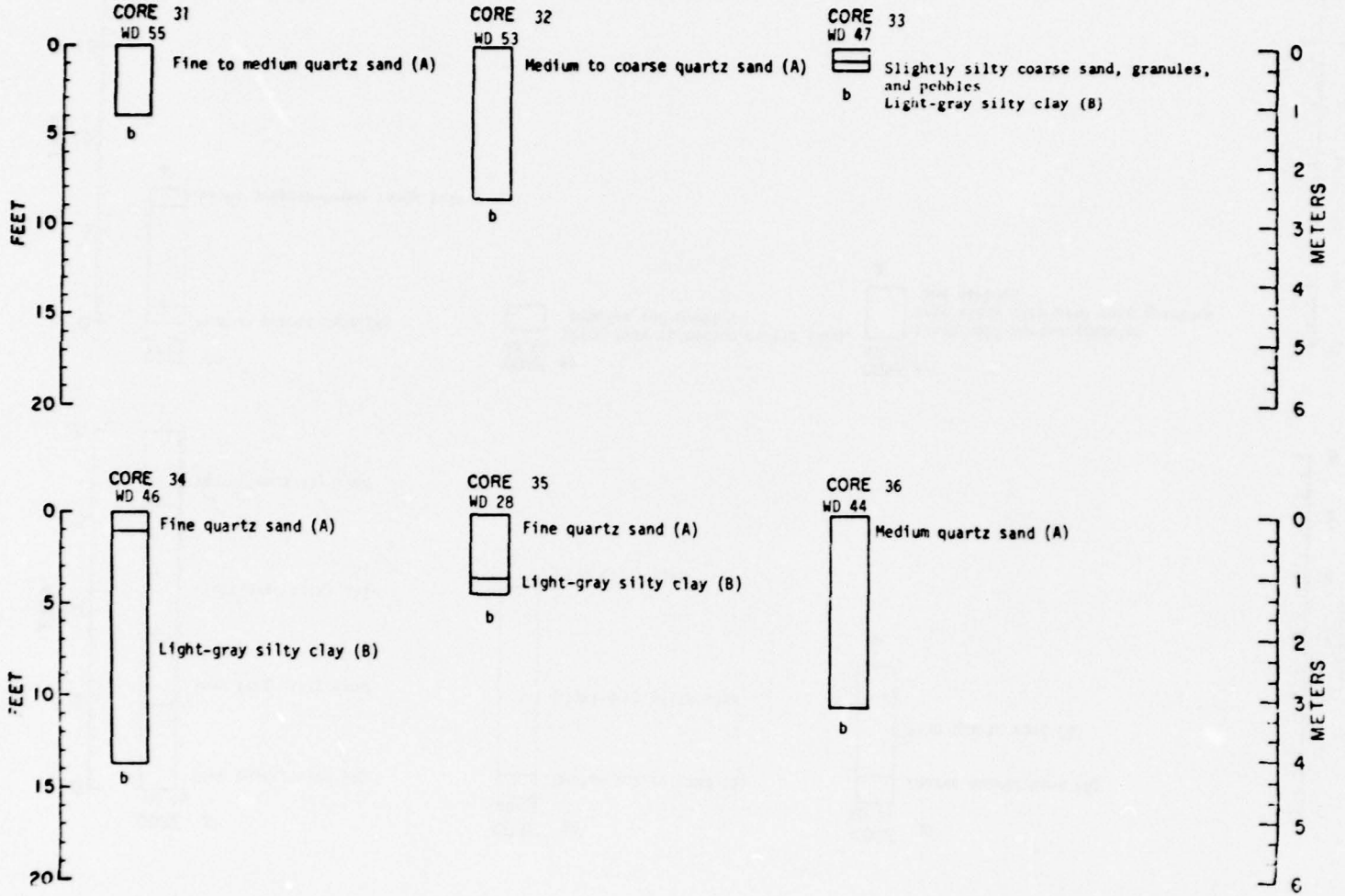

CORE 1
WD 36
Medium quartz sand (A)
Brownish-gray silt
b
CORE 2
WD 39
Medium quartz sand (A)
Coarse quartz sand (A)
Brownish-gray sandy silt
Pale brown, fine quartz sand
b
CORE 3
WD 61
Pinkish-gray clay
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 4
WD 27
Fine to medium quartz sand (A)
b
CORE 5
WD 40
Fine quartz sand (A)
b
CORE 6
WD 52
Medium quartz sand (A)
Pinkish-gray clay
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6

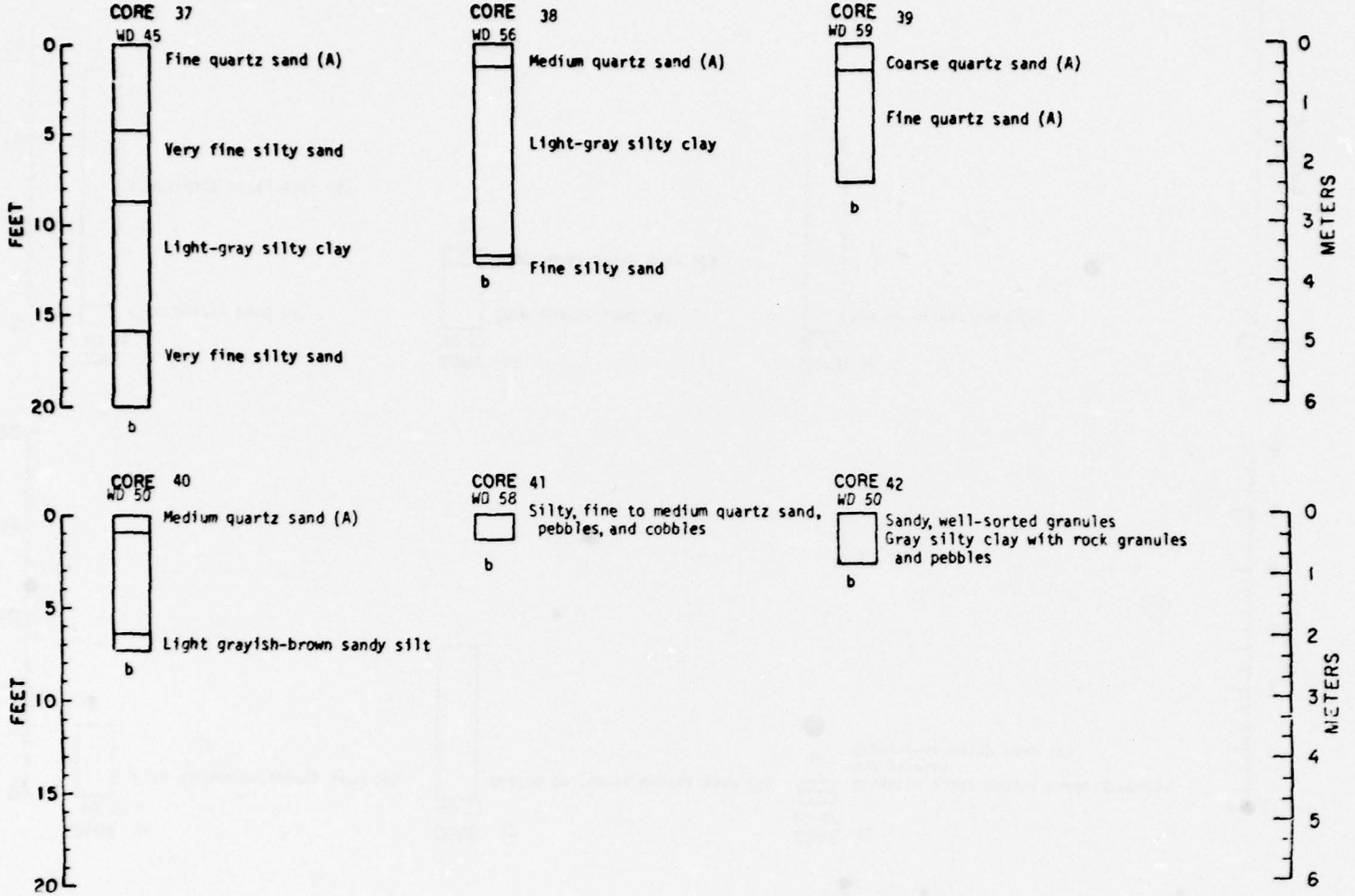

CORE 7
WD 46
Medium quartz sand (A)
Gray sandy silt
Brownish-gray silty sand
b
CORE 8
WD 67
Fine to medium quartz sand (A)
Fine quartz sand with large wood fragments
Fine quartz sand (A)
b
CORE 9
WD 62
Medium quartz sand (A)
Medium quartz sand with abundant plant fragments (A)
Medium quartz sand becoming coarse near bottom (A)
b
CORE 10
WD 24
Fine quartz sand (A)
Coarse to very coarse quartz sand and granules (A)
Fine quartz sand (A)
b
CORE 11
WD 72
Fine quartz sand (A)
b
CORE 12
WD 63
Fine quartz sand (A)
Medium quartz sand and granules (A)
Fine silty quartz sand (A)
Fine, clean quartz sand (A)
Fine silty quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6

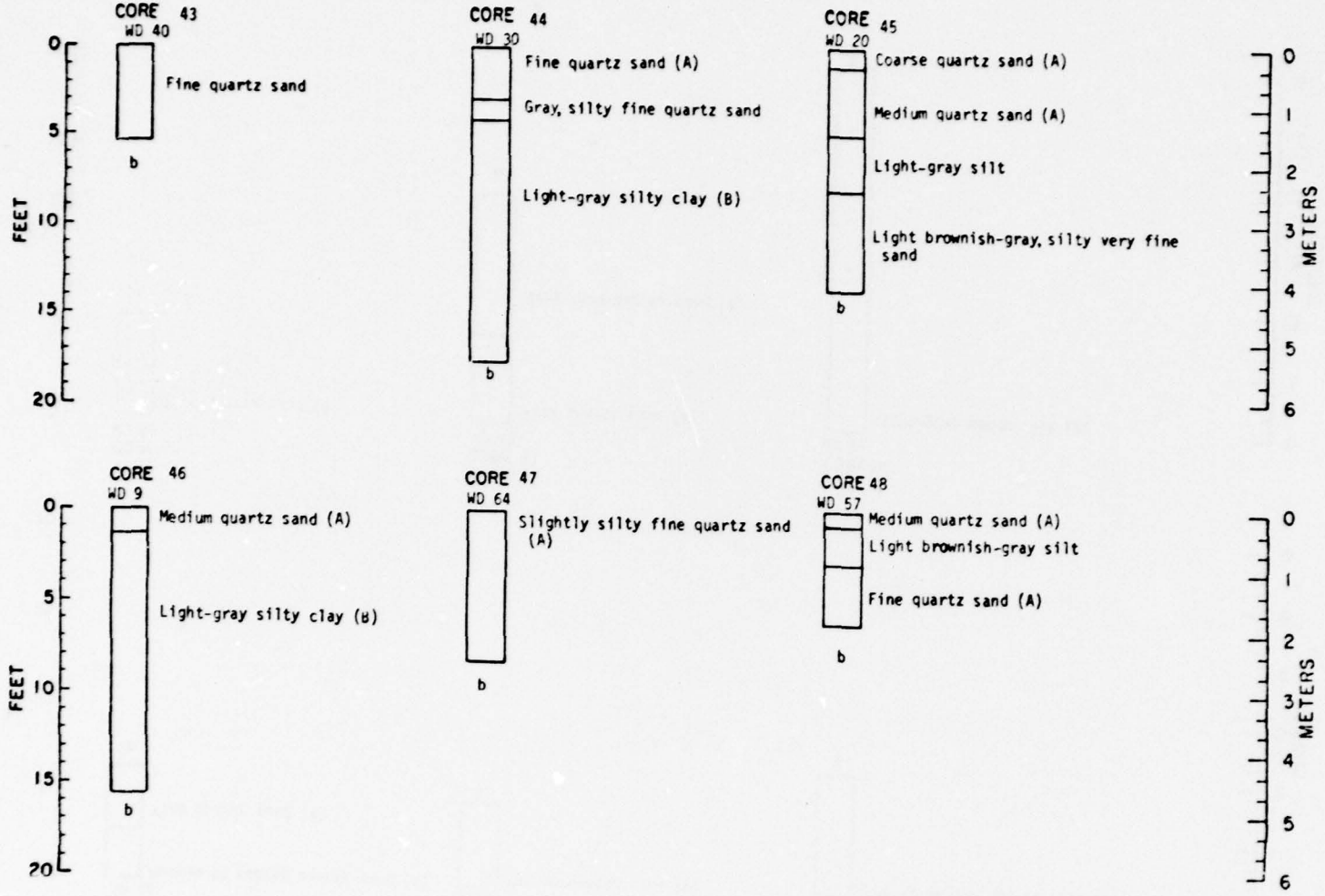

CORE 13
WD 61
Fine quartz sand (A)
Pinkish-gray, fine to very fine quartz sand
b
CORE 14
WD 52
Coarse quartz sand (A)
Fine quartz sand (A)
Medium quartz sand (A)
b
CORE 15
WD 44
Medium quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 16
WD 41
Medium to coarse quartz sand (A)
b
CORE 17
WD 45
Medium quartz sand (A)
b
CORE 18
WD 47
Medium quartz sand (A)
b

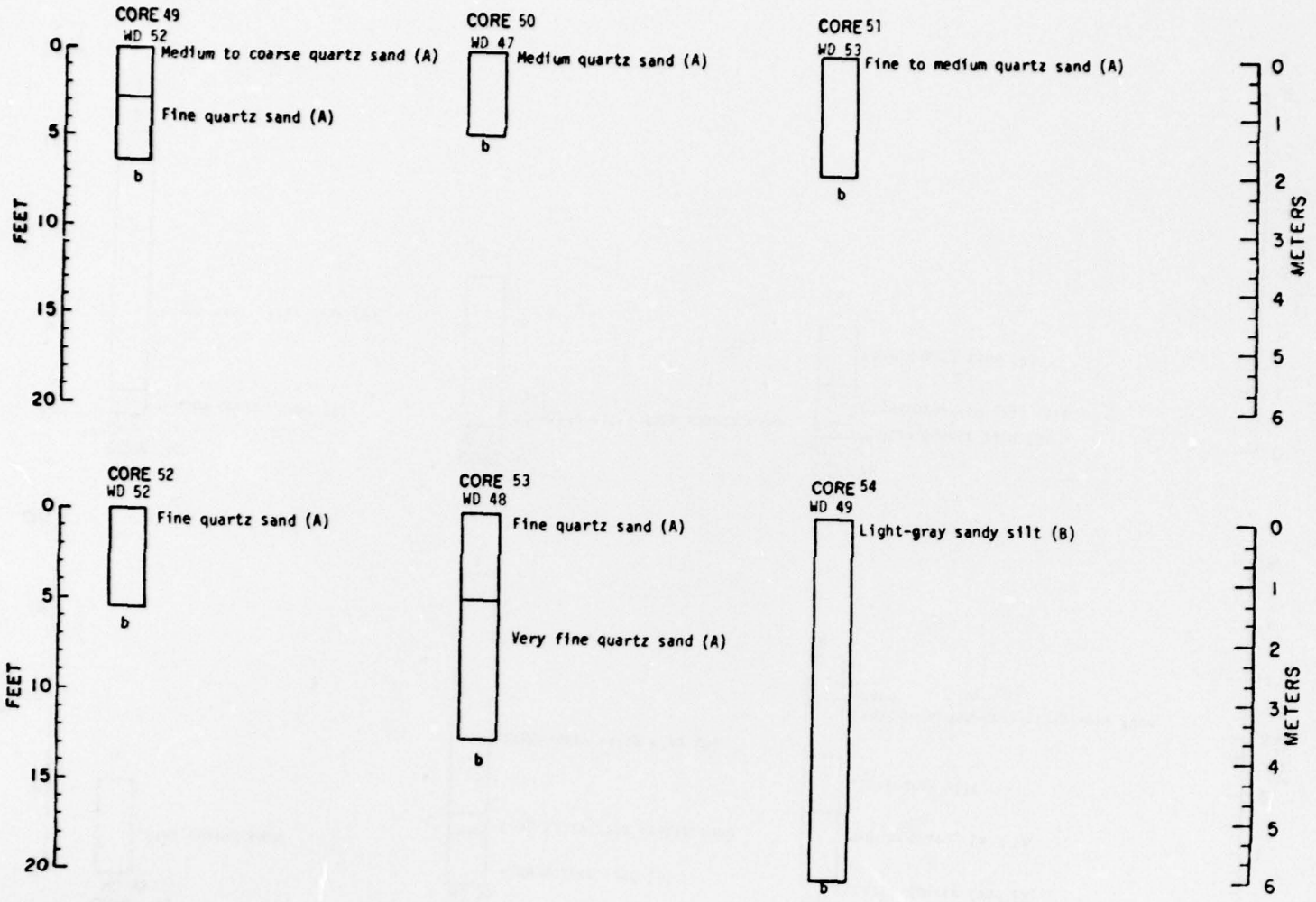

CORE 19
WD 50
Fine quartz sand (A)
b
CORE 20
WD 81
Fine to medium quartz sand (A)
b
CORE 21
WD 80
Fine quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 22
WD 68
Fine quartz sand (A)
Very silty, fine quartz sand
Medium quartz sand (A)
Fine quartz sand (A)
b
CORE 23
WD 49
Fine to medium quartz sand (A)
b
CORE 24
WD 52
Medium quartz sand (A)
Fine quartz sand (A)
b

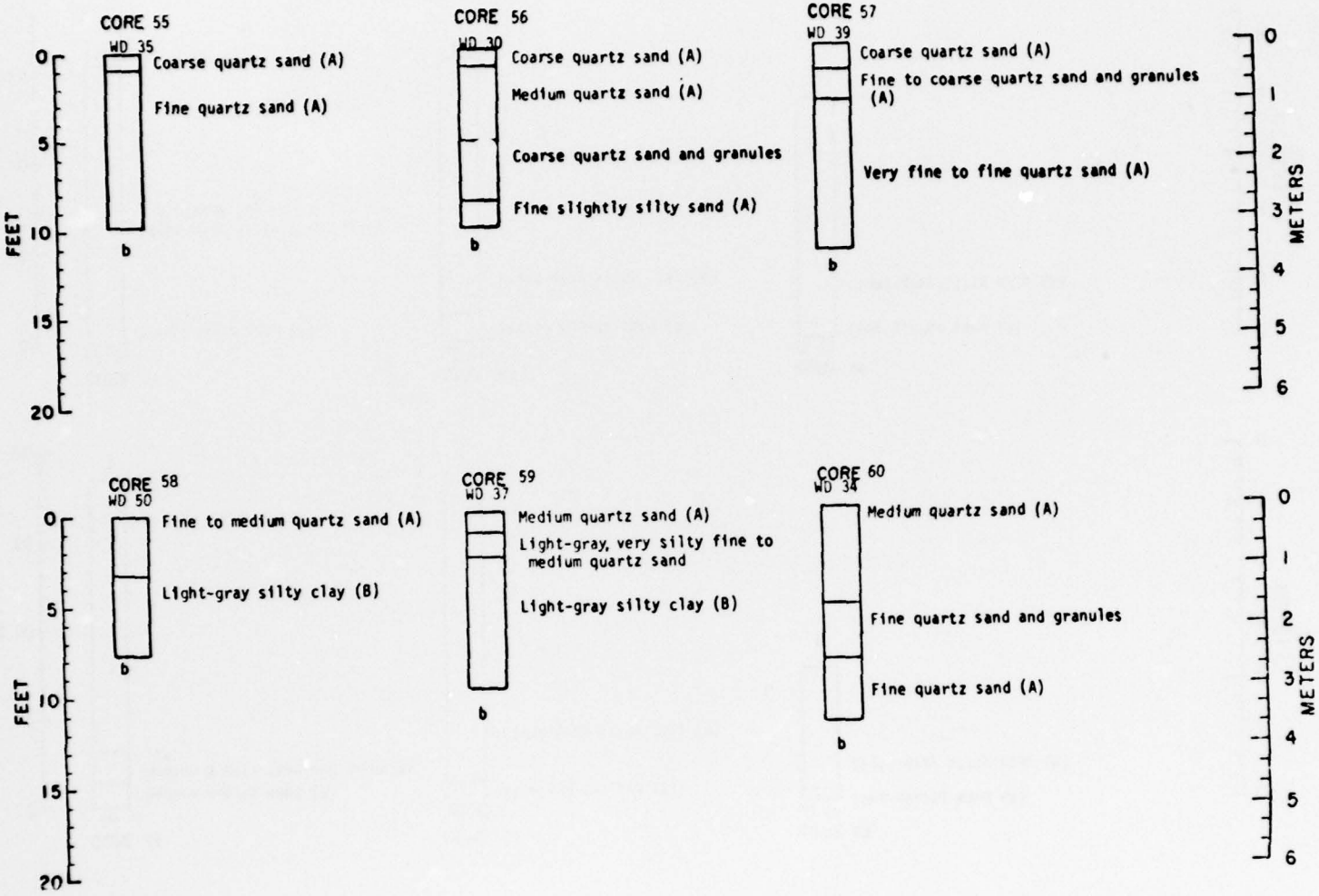

CORE 25
WD 64
Fine to medium quartz sand (A)
Fine silty quartz sand (A)
b
CORE 26
WD 44
Fine to medium quartz sand (A)
Very fine to fine silty quartz sand (A)
b
CORE 27
WD 47
Medium quartz sand
b
CORE 28
WD 43
Fine to medium quartz sand (A)
b
CORE 29
WD 39
Fine to medium quartz sand (A)
b
CORE 30
WD 49
Fine quartz sand (A)
Clean coarse sand, granules, and pebbles
Fine quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6

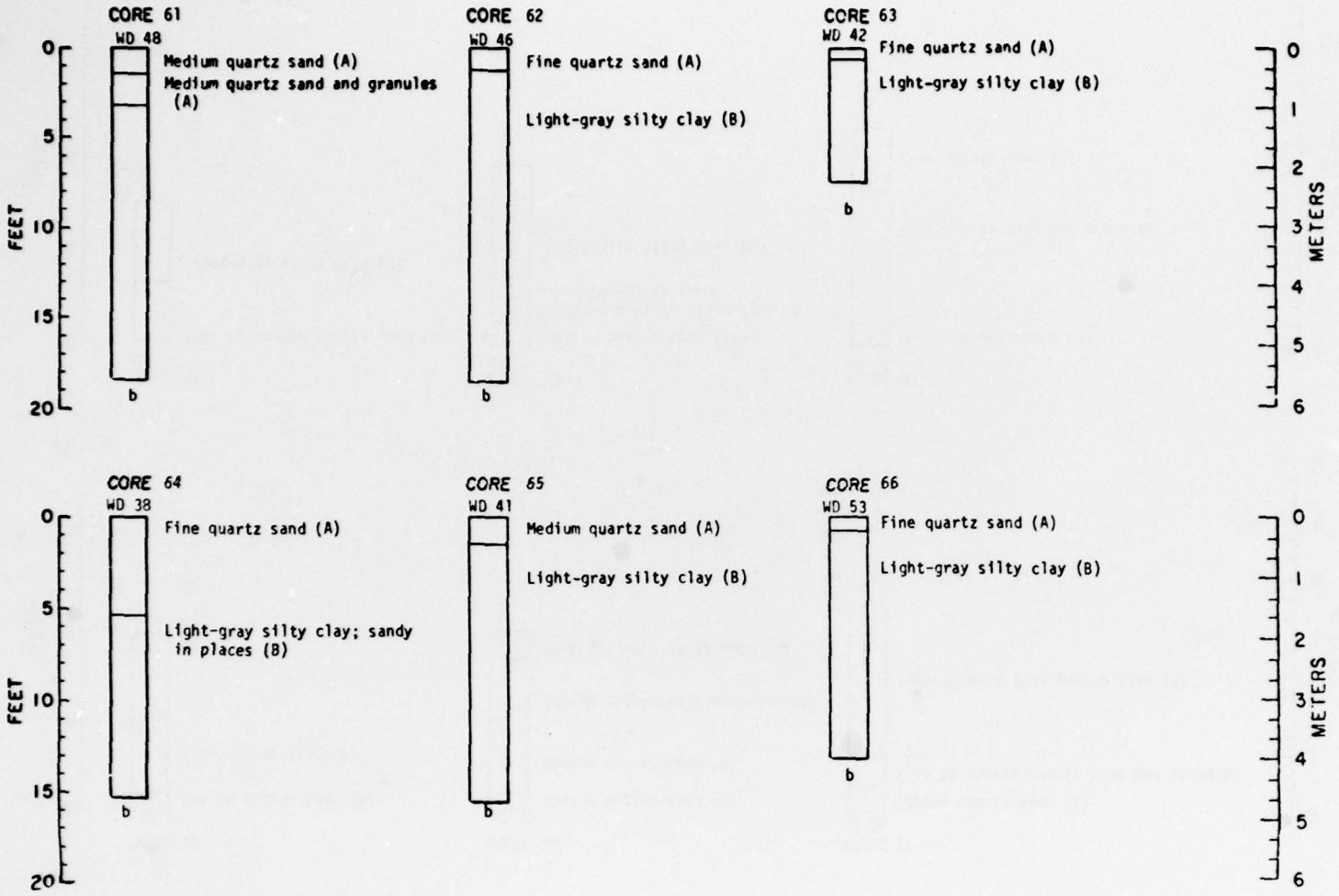

CORE 31
WD 55
Fine to medium quartz sand (A)
b
CORE 32
WD 53
Medium to coarse quartz sand (A)
b
CORE 33
WD 47
Slightly silty coarse sand, granules, and pebbles
Light-gray silty clay (B)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 34
WD 46
Fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 35
WD 28
Fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 36
WD 44
Medium quartz sand (A)
b

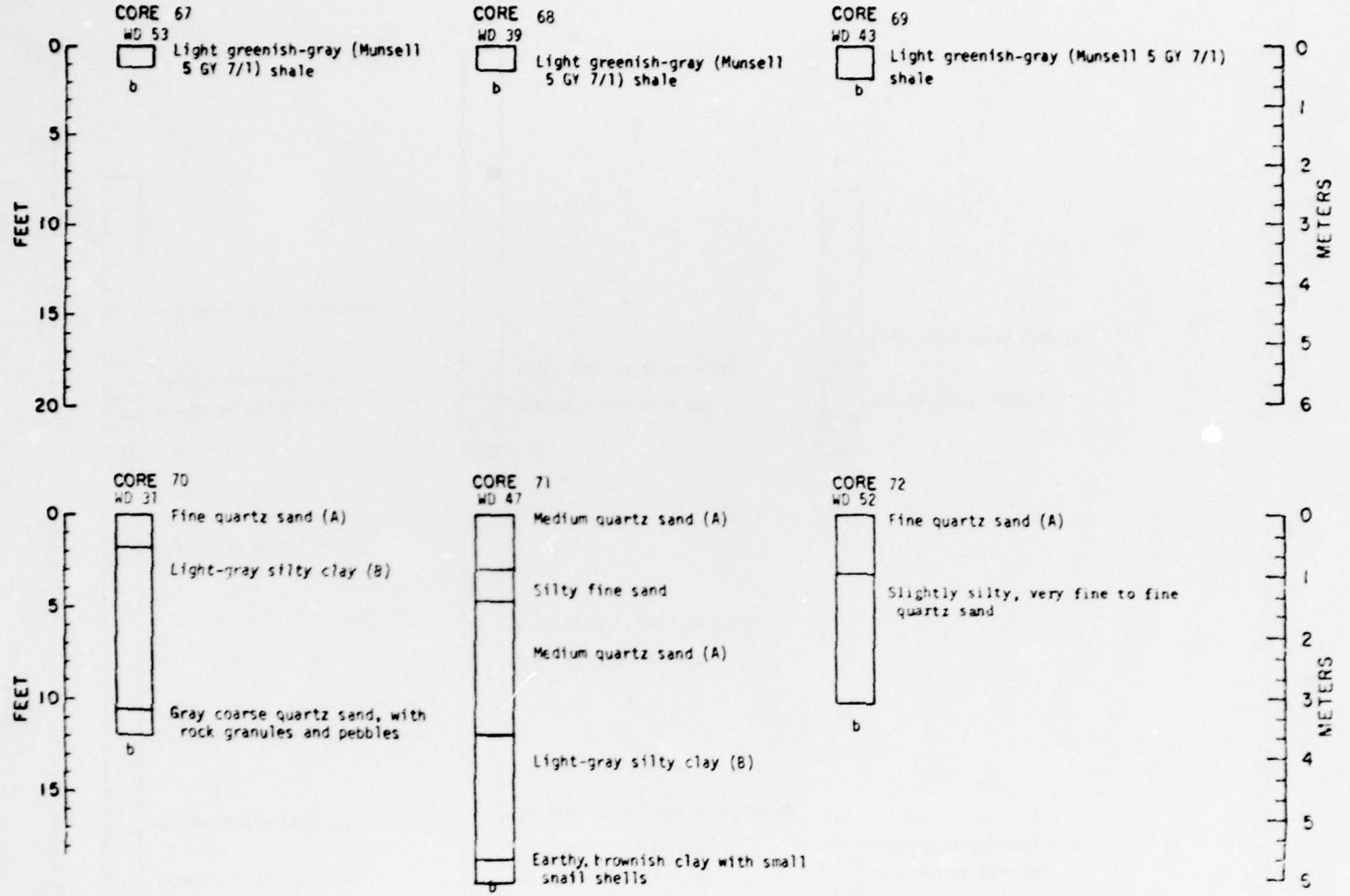

CORE 37
WD 45
Fine quartz sand (A)
Very fine silty sand
Light-gray silty clay
Very fine silty sand
b
CORE 38
WD 56
Medium quartz sand (A)
Light-gray silty clay
Fine silty sand
b
CORE 39
WD 59
Coarse quartz sand (A)
Fine quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 40
WD 50
Medium quartz sand (A)
Light grayish-brown sandy silt
b
CORE 41
WD 58
Silty, fine to medium quartz sand, pebbles, and cobbles
b
CORE 42
WD 50
Sandy, well-sorted granules
Gray silty clay with rock granules and pebbles
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6

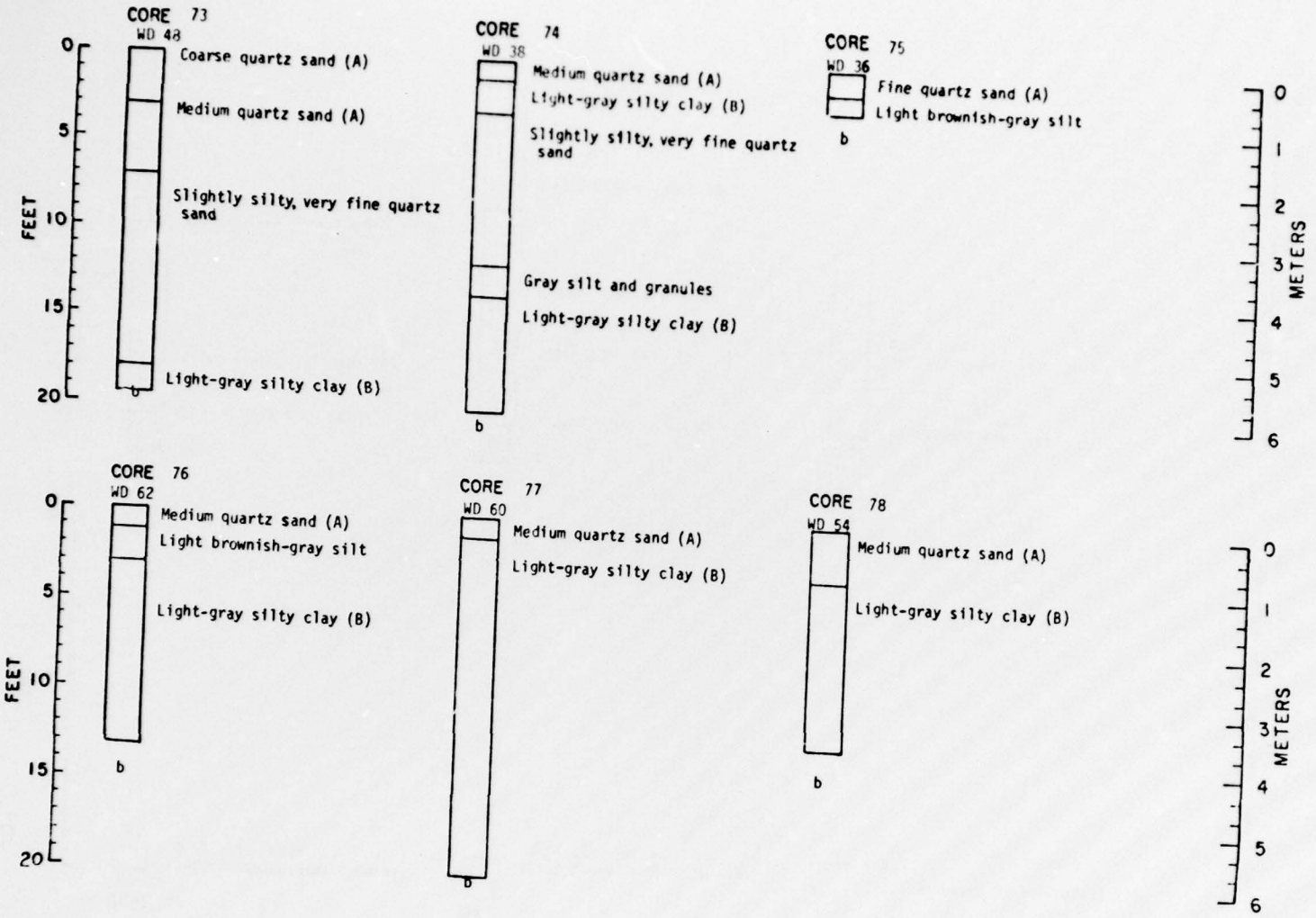

CORE 43
WD 40
Fine quartz sand
b
CORE 44
WD 30
Fine quartz sand (A)
Gray, silty fine quartz sand
Light-gray silty clay (B)
b
CORE 45
WD 20
Coarse quartz sand (A)
Medium quartz sand (A)
Light-gray silt
Light brownish-gray, silty very fine sand
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 46
WD 9
Medium quartz sand (A)
Light-gray silty clay (B)
b
CORE 47
WD 64
Slightly silty fine quartz sand (A)
b
CORE 48
WD 57
Medium quartz sand (A)
Light brownish-gray silt
Fine quartz sand (A)
b

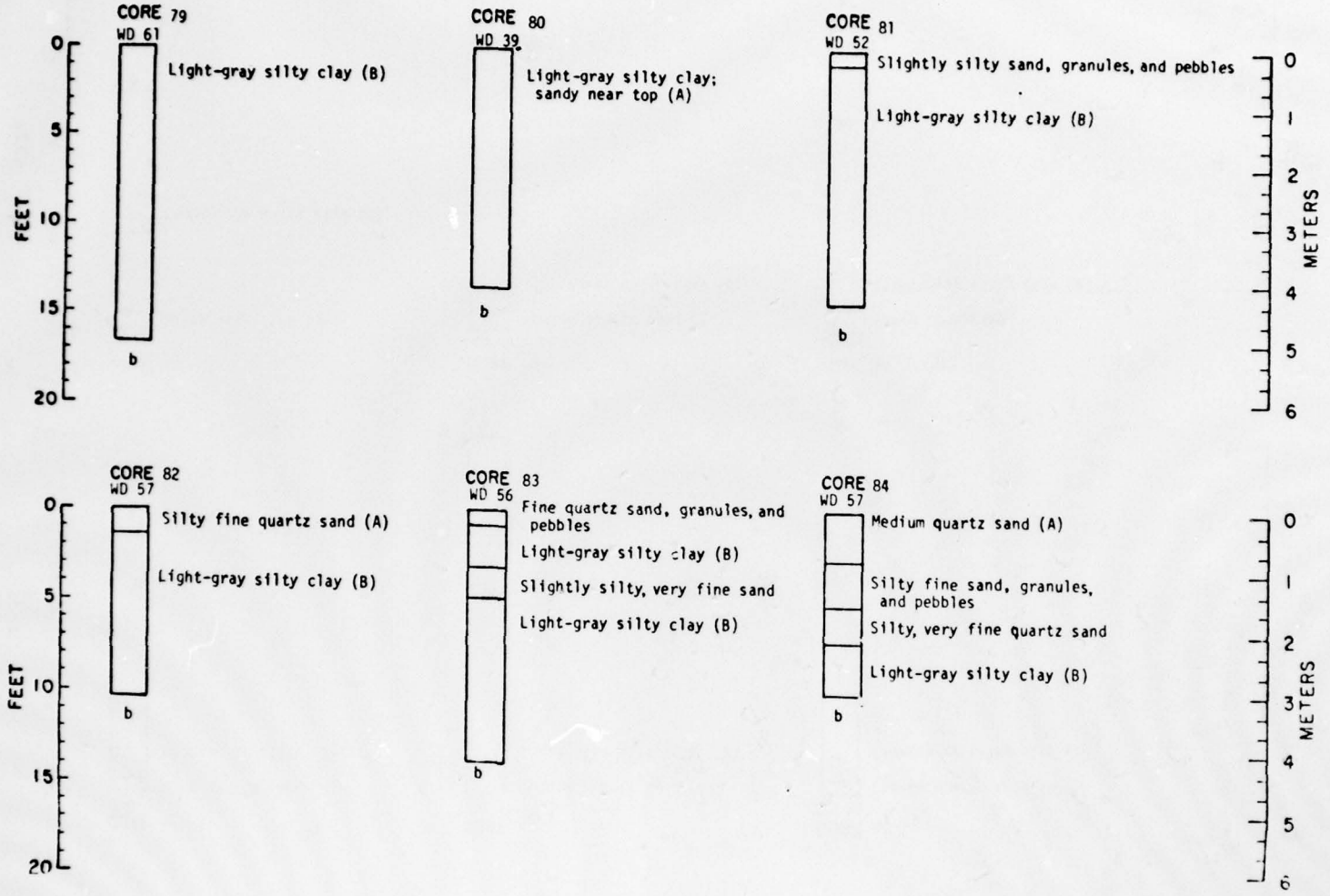

CORE 49
WD 52
Medium to coarse quartz sand (A)
Fine quartz sand (A)
b
CORE 50
WD 47
Medium quartz sand (A)
b
CORE 51
WD 53
Fine to medium quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 52
WD 52
Fine quartz sand (A)
b
CORE 53
WD 48
Fine quartz sand (A)
Very fine quartz sand (A)
b
CORE 54
WD 49
Light-gray sandy silt (B)
b

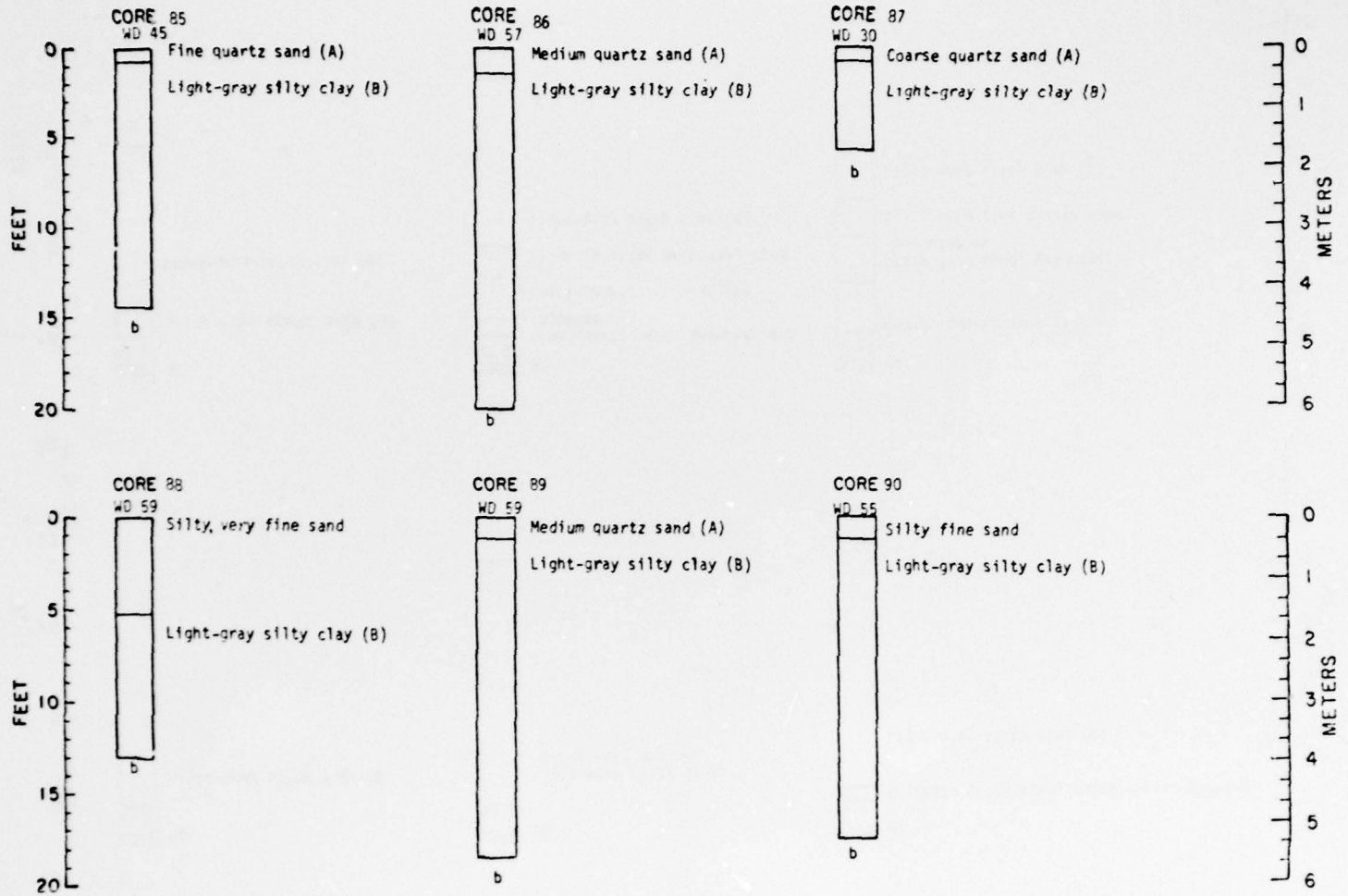

CORE 55
WD 35
Coarse quartz sand (A)
Fine quartz sand (A)
b
CORE 56
WD 30
Coarse quartz sand (A)
Medium quartz sand (A)
Coarse quartz sand and granules
Fine slightly silty sand (A)
b
CORE 57
WD 39
Coarse quartz sand (A)
Fine to coarse quartz sand and granules (A)
Very fine to fine quartz sand (A)
b
CORE 58
WD 50
Fine to medium quartz sand (A)
Light-gray silty clay (B)
b
CORE 59
WD 37
Medium quartz sand (A)
Light-gray, very silty fine to medium quartz sand
Light-gray silty clay (B)
b
CORE 60
WD 34
Medium quartz sand (A)
Fine quartz sand and granules
Fine quartz sand (A)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6


CORE 61
WD 48
Medium quartz sand (A)
Medium quartz sand and granules (A)
b
CORE 62
WD 46
Fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 63
WD 42
Fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 64
WD 38
Fine quartz sand (A)
Light-gray silty clay; sandy in places (B)
b
CORE 65
WD 41
Medium quartz sand (A)
Light-gray silty clay (B)
b
CORE 66
WD 53
Fine quartz sand (A)
Light-gray silty clay (B)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6


CORE 67
WD 53
Light greenish-gray (Munsell 5 GY 7/1) shale
b
CORE 68
WD 39
Light greenish-gray (Munsell 5 GY 7/1) shale
b
CORE 69
WD 43
Light greenish-gray (Munsell 5 GY 7/1) shale
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 70
WD 31
Fine quartz sand (A)
Light-gray silty clay (B)
Gray coarse quartz sand, with rock granules and pebbles
b
CORE 71
WD 47
Medium quartz sand (A)
Silty fine sand
Medium quartz sand (A)
Light-gray silty clay (B)
Earthy, brownish clay with small snail shells
b
CORE 72
WD 52
Fine quartz sand (A)
Slightly silty, very fine to fine quartz sand
b


CORE 73
WD 48
Coarse quartz sand (A)
Medium quartz sand (A)
Slightly silty, very fine quartz sand
Light-gray silty clay (B)
b
CORE 74
WD 38
Medium quartz sand (A)
Light-gray silty clay (B)
Slightly silty, very fine quartz sand
Gray silt and granules
Light-gray silty clay (B)
b
CORE 75
WD 36
Fine quartz sand (A)
Light brownish-gray silt
b
CORE 76
WD 62
Medium quartz sand (A)
Light brownish-gray silt
Light-gray silty clay (B)
b
CORE 77
WD 60
Medium quartz sand (A)
Light-gray silty clay (B)
b
CORE 78
WD 54
Medium quartz sand (A)
Light-gray silty clay (B)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6


CORE 79
WD 61
Light-gray silty clay (B)
b
CORE 80
WD 39
Light-gray silty clay; sandy near top (A)
b
CORE 81
WD 52
Slightly silty sand, granules, and pebbles
Light-gray silty clay (B)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6
CORE 82
WD 57
Silty fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 83
WD 56
Fine quartz sand, granules, and pebbles
Light-gray silty clay (B)
Slightly silty, very fine sand
Light-gray silty clay (B)
b
CORE 84
WD 57
Medium quartz sand (A)
Silty fine sand, granules, and pebbles
Silty, very fine quartz sand
Light-gray silty clay (B)
b


CORE 85
WD 45
Fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 86
WD 57
Medium quartz sand (A)
Light-gray silty clay (B)
b
CORE 87
WD 30
Coarse quartz sand (A)
Light-gray silty clay (B)
b
CORE 88
WD 59
Silty, very fine sand
Light-gray silty clay (B)
b
CORE 89
WD 59
Medium quartz sand (A)
Light-gray silty clay (B)
b
CORE 90
WD 55
Silty fine sand
Light-gray silty clay (B)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6

CORE 91
WD 55
Silty, very fine to fine sand
Light-gray silty clay (B)
b
CORE 92
WD 51
Fine quartz sand (A)
Light-gray silty clay (B)
b
CORE 93
WD 45
Light-gray silty clay (B)
b
FEET
0
5
10
15
20
METERS
0
1
2
3
4
5
6

APPENDIX C

GRANULOMETRIC DATA

This appendix contains size distribution data for selected samples extracted from the Lake Michigan ICONS cores. Size data on sand samples determined by the fall velocity method in a Rapid Sediment Analyzer are presented in Table C-1. Table C-2 contains size distribution data for selected sand and gravel samples determined by standard sieve analysis.

Table C-1. Distribution of size classes by frequency percentages.

REFERENCE		SIZE CLASS													STATISTICAL PARAMETERS				
CORE NO.	INT (FT)	-1.000 -2.000	-.500 -1.414	.000 1.000	.500 .707	1.000 .500	1.500 .354	2.000 .250	2.500 .177	3.000 .125	3.500 .088	4.000 .062	PAN	PHI MM.	MEDIAN PHI	MEDIAN MM.	MEAN PHI	MEAN MM.	S.D. PHI
1	TOP	0.00	0.00	0.00	.07	2.15	10.68	23.99	26.89	25.89	2.35	0.00	0.00		2.04	.234	2.00	.240	.57
1	-2.0	0.00	.19	1.97	1.96	14.53	11.50	19.00	25.97	19.01	5.33	0.00	0.00		2.01	.249	1.88	.272	.79
2	TOP	0.00	0.00	0.00	.19	12.04	10.54	14.20	23.57	23.65	10.44	5.31	0.00		2.29	.204	2.18	.220	.82
2	-4.0	0.00	0.00	.37	3.13	40.66	22.24	14.10	10.11	9.31	0.00	0.00	0.00		1.10	.466	1.33	.398	.69
2	-8.3	0.00	0.00	0.00	0.00	0.00	0.00	10.91	22.10	32.48	20.74	7.77	0.00		2.07	.157	2.00	.158	.54
4	TOP	0.00	0.00	.11	.81	1.51	2.28	28.70	44.95	19.18	2.47	0.00	0.00		2.20	.218	2.15	.225	.68
5	TOP	0.00	.44	.71	.36	.42	2.12	32.65	42.03	18.55	2.74	0.00	0.00		2.17	.225	2.13	.229	.52
6	TOP	0.00	.15	.70	.67	2.34	27.94	28.92	19.96	16.75	2.68	0.00	0.00		1.77	.293	1.87	.273	.82
7	TOP	0.00	0.00	0.00	.03	1.07	4.70	25.95	28.35	31.25	8.65	0.00	0.00		2.36	.195	2.30	.204	.54
8	TOP	0.00	0.00	.24	.43	1.11	21.45	10.04	20.98	21.95	13.24	5.56	0.00		2.24	.211	2.21	.217	.76
8	-2.0	0.00	.05	1.25	.80	5.77	33.02	23.51	20.22	11.92	2.80	0.00	0.00		1.65	.318	1.74	.300	.68
8	-4.0	0.00	0.00	0.00	.32	1.59	45.23	31.70	10.84	4.20	0.00	0.00	0.00		1.55	.343	1.64	.321	.83
9	TOP	0.00	0.00	.03	.93	1.43	19.38	30.43	24.65	16.89	6.07	0.00	0.00		1.95	.260	2.01	.249	.59
9	-2.0	0.00	0.00	.15	1.20	1.09	52.85	18.41	9.71	5.41	9.02	3.70	0.00		1.45	.367	1.75	.297	.78
9	-4.0	0.00	.19	.45	1.10	.13	50.37	27.77	15.97	4.02	0.00	0.00	0.00		1.48	.359	1.57	.336	.68
9	-8.5	0.00	0.00	.78	1.28	52.42	27.90	9.02	0.04	0.00	0.00	0.00	0.00		.97	.511	1.10	.467	.68
10	TOP	0.00	0.00	.20	2.50	5.04	2.47	23.52	30.95	25.80	0.00	0.00	0.00		2.25	.210	2.10	.233	.59
10	-8.0	0.00	0.00	.80	7.94	11.84	3.08	24.21	31.21	20.80	0.00	0.00	0.00		2.04	.243	1.85	.278	.78
10	-10.0	0.00	5.24	16.37	59.32	8.96	5.51	4.79	0.00	0.00	0.00	0.00	0.00		.20	.834	.29	.819	.51
10	-12	0.00	1.20	1.73	.29	.32	1.00	10.59	48.91	33.00	2.84	0.00	0.00		2.38	.193	2.29	.205	.60
11	TOP	0.00	0.00	3.97	3.83	1.87	5.25	16.15	16.48	43.24	7.29	0.00	0.00		2.51	.176	2.20	.217	.83
12	TOP	0.00	0.00	0.00	0.00	0.00	9.37	17.85	33.91	34.83	4.03	0.00	0.00		2.35	.196	2.29	.205	.50
12	-2.0	0.00	6.10	19.31	7.91	14.52	13.04	12.80	12.91	10.52	2.83	0.00	0.00		1.09	.466	1.10	.466	1.12
12	-4.0	0.00	0.00	0.00	0.00	0.00	9.27	30.99	22.23	16.41	12.40	8.70	0.00		2.22	.215	2.33	.199	.72
13	TOP	0.00	0.00	0.00	0.00	1.04	5.04	9.34	13.50	25.00	33.79	10.45	0.00		2.90	.134	2.74	.149	.70
14	TOP	0.00	.42	1.41	.27	2.43	27.89	24.74	20.56	18.95	3.33	0.00	0.00		1.82	.284	1.86	.271	.69
14	-2.0	0.00	0.00	.01	3.78	17.20	14.52	10.08	17.24	26.57	10.00	0.00	0.00		1.92	.264	1.87	.274	.89
14	-4.0	0.00	0.00	.74	2.14	6.78	10.65	10.75	20.96	27.91	10.56	3.31	0.00		2.33	.199	2.20	.218	.81
15	TOP	0.00	.54	1.33	2.54	9.15	28.70	10.22	23.01	20.45	5.41	0.00	0.00		1.99	.252	1.87	.274	.80
15	-2.0	0.00	.34	.55	1.00	5.77	28.60	20.19	20.44	19.55	3.39	0.00	0.00		1.82	.283	1.87	.274	.70
15	-2.0	0.00	.03	7.37	4.83	6.09	25.70	18.67	14.59	17.12	5.74	0.00	0.00		1.64	.320	1.67	.315	.90
15	-6.0	0.00	0.00	0.00	0.00	1.07	32.30	18.65	22.53	21.79	3.38	0.00	0.00		1.94	.261	1.97	.256	.61
15	-8.0	0.00	2.91	4.35	.70	1.98	17.42	18.28	25.64	16.78	10.40	3.49	0.00		2.06	.237	1.99	.252	.97
15	-11.0	0.00	0.00	0.00	.10	1.70	20.44	33.70	25.09	12.35	0.00	0.00	0.00		1.81	.286	1.87	.273	.48
16	TOP	0.00	0.00	0.00	0.00	1.83	20.75	22.36	25.12	26.56	3.37	0.00	0.00		2.10	.233	2.07	.238	.60
16	-2.0	0.00	1.52	1.25	.37	1.98	42.42	29.06	15.39	8.01	0.00	0.00	0.00		1.56	.344	1.60	.330	.61
16	-4.0	0.00	0.00	0.00	.85	.26	42.27	29.82	17.56	9.30	0.00	0.00	0.00		1.62	.328	1.71	.305	.50
17	TOP	0.00	0.00	0.00	0.00	0.00	1.30	33.20	20.09	29.46	12.50	5.70	0.00		2.31	.202	2.37	.194	.62
18	TOP	0.00	0.00	0.00	0.00	.70	25.45	25.30	15.32	18.45	8.41	6.31	0.00		1.97	.256	2.12	.229	.76
18	-4.0	0.00	.23	.90	1.37	4.41	38.14	28.53	15.09	11.57	3.10	0.00	0.00		1.60	.330	1.71	.306	.66
19	TOP	0.00	0.00	5.17	4.27	14.38	14.08	17.30	18.74	19.27	6.78	0.00	0.00		1.84	.280	1.75	.297	.93
19	-2.0	0.00	.20	.39	.66	.52	2.74	10.53	19.01	24.81	20.78	14.36	0.00		2.69	.155	2.64	.160	.75
20	TOP	0.00	0.00	0.00	0.00	.25	2.83	19.54	27.15	30.30	18.07	1.85	0.00		2.50	.170	2.48	.179	.56
20	-2.0	0.00	0.00	.20	1.04	4.01	14.30	17.79	20.36	26.29	15.89	0.00	0.00		2.32	.200	2.22	.215	.74
-4.	0	0.00	.23	.32	.33	1.12	18.83	28.40	34.03	14.73	0.00	0.00	0.00		2.01	.246	1.98	.254	.53
21	TOP	0.00	0.00	0.00	.04	1.14	9.50	15.31	20.10	28.37	23.02	2.48	0.00		2.57	.168	2.47	.181	.48
22	TOP	0.00	.20	.83	1.46	2.16	12.52	11.46	18.54	33.97	18.86	0.00	0.00		2.55	.171	2.34	.197	.76
22	-4.0	0.00	0.00	0.00	.03	1.44	33.55	34.22	24.29	6.47	0.00	0.00	0.00		1.68	.312	1.75	.296	.44
22	-8.0	0.00	0.00	0.00	0.00	0.00	25.10	32.00	34.28	7.89	0.00	0.00	0.00		1.87	.274	1.88	.271	.41

Table C-1. Distribution of size classes by frequency percentages.--Continued

REFERENCE		SIZE CLASS												STATISTICAL PARAMETERS				
CORE	INT	>1.000	-.500	.000	.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	PAN	PHI	MEDIAN	MEAN		S.O.
NO.	(FT.)	-2.000	-1.414	-1.000	-.707	-.500	-.354	-.250	-.177	-.125	-.088	-.062	PAN	MM.	PHI	MM.	PHI	MM.	PHI
23	TOP	0.00	0.00	0.00	0.00	.71	20.90	23.71	23.53	17.16	7.99	0.00	0.00		1.97	.255	2.03	.245	.80
24	TOP	0.00	0.00	.08	1.94	15.71	30.49	21.24	14.79	9.74	0.00	0.00	0.00		1.45	.366	1.57	.338	.61
24	-2.0	0.00	0.00	0.00	0.00	.09	39.83	30.08	13.32	5.74	9.25	1.70	0.00		1.04	.520	1.45	.270	.67
24	-4.0	0.00	.65	1.11	1.10	1.90	11.81	18.08	28.56	30.48	6.11	0.00	0.00		2.30	.203	2.10	.224	.71
24	-6.0	0.00	.21	1.07	3.54	31.27	21.97	15.94	15.80	10.15	0.00	0.00	0.00		1.34	.395	1.84	.367	.70
24	-8.0	0.00	0.00	0.00	0.00	.13	1.23	12.93	18.05	40.91	21.32	5.42	0.00		2.74	.189	2.67	.157	.53
25	TOP	0.00	0.00	0.00	0.00	.49	15.70	24.01	22.80	18.63	12.86	4.83	0.00		2.20	.218	2.24	.211	.70
25	-2.0	0.00	0.00	8.02	14.00	12.59	10.10	8.31	12.37	14.54	13.50	5.96	0.00		1.82	.283	1.73	.302	1.21
25	-4.0	0.00	1.15	.83	.16	.15	.51	18.86	30.42	27.29	14.32	6.70	0.00		2.48	.180	2.48	.180	.69
26	TOP	0.00	0.00	0.00	0.00	.04	7.15	15.93	26.10	30.36	11.40	0.00	0.00		2.51	.176	2.40	.190	.54
26	-2.0	0.00	0.00	0.00	.87	5.37	10.25	15.75	18.38	30.56	12.80	0.00	0.00		2.36	.196	2.19	.218	.76
26	-4.0	0.00	2.20	4.57	4.08	9.79	8.01	13.70	15.75	23.75	12.78	5.29	0.00		2.28	.205	2.01	.248	1.10
26	-6.0	0.00	0.00	0.00	.29	.55	1.02	9.85	13.24	29.22	31.26	14.57	0.00		2.93	.131	2.85	.139	.61
27	TOP	0.00	0.00	0.00	.31	2.09	13.03	13.68	20.23	35.07	8.99	0.00	0.00		2.42	.187	2.28	.205	.62
27	-2.0	0.00	.09	1.09	2.69	18.34	35.68	20.82	10.63	8.69	1.97	0.00	0.00		1.32	.400	1.48	.360	.70
27	-4.0	0.00	0.00	2.04	.20	1.83	30.36	30.33	24.38	10.86	0.00	0.00	0.00		1.74	.299	1.76	.295	.54
28	TOP	0.00	0.00	1.86	.58	2.38	10.23	23.97	21.50	25.82	7.65	0.00	0.00		2.12	.230	2.07	.238	.71
28	-2.0	0.00	0.00	.15	.79	1.70	13.37	22.78	25.64	29.01	8.59	0.00	0.00		2.26	.208	2.19	.220	.63
28	-4.0	0.00	.15	1.14	1.08	4.93	25.53	18.75	23.35	14.49	6.57	0.00	0.00		1.96	.258	1.93	.262	.73
28	-6.0	0.00	1.17	2.83	3.26	8.01	5.03	11.99	18.41	27.23	21.21	0.86	0.00		2.60	.165	2.33	.199	1.02
28	-7.7	0.00	0.00	0.00	0.00	0.00	0.86	27.91	30.85	22.16	12.20	0.00	0.00		2.22	.214	2.27	.208	.56
29	TOP	0.00	0.00	.22	1.46	8.58	21.89	30.87	16.14	16.74	6.15	0.00	0.00		1.79	.288	1.88	.271	.68
29	-2.0	0.00	0.00	0.00	0.00	1.97	20.72	25.84	22.54	18.07	3.06	0.00	0.00		1.87	.273	1.91	.265	.61
29	-4.6	0.00	0.00	0.00	.00	8.78	37.42	22.49	10.62	14.24	2.84	0.00	0.00		1.63	.322	1.74	.300	.64
29	-6.0	0.00	0.00	0.00	0.00	0.21	30.29	10.63	10.25	23.20	7.35	0.00	0.00		1.88	.272	1.95	.260	.73
29	-8.0	0.00	5.46	15.08	12.78	18.71	15.89	10.47	8.14	11.84	2.48	0.00	0.00		.95	.518	1.05	.488	1.08
29	-10	0.00	0.00	0.00	0.00	.42	19.17	36.32	24.71	9.23	9.51	1.04	0.00		1.91	.267	2.04	.243	.66
30	TOP	0.00	0.00	0.00	0.00	.07	20.08	26.29	22.41	21.35	3.21	0.00	0.00		1.94	.266	2.00	.250	.58
30	-4.6	0.00	3.48	6.91	20.81	31.07	10.85	9.70	8.31	9.26	0.00	0.00	0.00		.76	.615	.99	.505	.89
30	-8.5	0.00	.29	.40	2.16	8.37	15.68	15.38	21.35	24.88	10.42	1.07	0.00		2.24	.212	2.08	.238	.81
31	TOP	0.00	0.00	0.00	.18	1.62	11.22	13.70	24.98	34.69	13.62	0.00	0.00		2.07	.180	2.35	.197	.63
31	-3.8	0.00	.11	2.15	4.28	27.16	26.50	11.18	8.52	9.14	8.97	0.00	0.00		1.21	.432	1.48	.358	.89
32	TOP	0.00	.80	1.21	1.63	5.94	28.17	13.88	19.57	19.19	9.61	0.00	0.00		1.95	.258	1.90	.268	.84
32	-2.0	0.00	.38	3.25	6.07	26.42	17.14	20.19	15.46	8.94	2.24	0.00	0.00		1.39	.382	1.45	.367	.80
32	-4.0	0.00	0.00	0.00	0.00	1.86	31.37	36.51	24.55	5.91	0.00	0.00	0.00		1.71	.305	1.76	.296	.65
32	-6.0	0.00	0.00	0.00	.26	1.70	29.50	36.61	22.45	9.41	0.00	0.00	0.00		1.73	.302	1.80	.288	.67
33	TOP	0.00	1.88	9.90	11.68	36.71	8.79	4.96	5.93	7.33	9.64	5.15	0.00		.81	.571	1.27	.415	1.20
34	TOP	0.00	0.00	0.00	.57	3.11	7.35	9.72	19.13	40.48	15.75	3.92	0.00		2.66	.101	2.68	.179	.68
35	TOP	0.00	.53	.95	.28	1.43	3.09	10.08	26.46	40.66	10.69	0.00	0.00		2.51	.175	2.38	.192	.62
35	-2.0	0.00	0.00	0.00	0.00	.42	3.67	14.96	31.94	38.12	10.49	0.00	0.00		2.50	.177	2.64	.184	.69
36	TOP	0.00	0.00	.01	.21	1.38	7.52	24.23	21.11	31.32	14.22	0.00	0.00		2.41	.188	2.32	.200	.63
36	-4.0	0.00	3.12	2.23	3.72	8.85	17.50	14.62	22.94	15.79	9.52	2.86	0.00		1.95	.259	1.85	.277	.98
36	-10	0.00	0.00	0.00	0.00	.00	2.11	36.45	35.14	17.67	8.63	0.00	0.00		2.16	.224	2.19	.218	.50
37	TOP	0.00	1.70	.79	.40	.14	8.04	13.68	21.43	29.40	19.29	6.93	0.00		2.00	.185	2.49	.178	.80
37	-6.0	0.00	0.00	.20	.96	1.20	1.74	5.15	8.32	14.97	30.97	36.32	0.00		3.31	.101	3.06	.118	.74
38	TOP	0.00	0.00	.33	1.01	3.13	20.19	24.36	24.82	15.35	10.81	0.00	0.00		2.02	.247	2.03	.245	.70
39	TOP	0.00	2.67	12.52	9.23	20.93	21.33	10.52	8.28	8.87	5.67	0.00	0.00		1.10	.467	1.19	.437	1.02
39	-2.0	0.00	0.00	0.00	.01	.96	.47	31.39	26.09	25.11	12.24	3.63	0.00		2.37	.193	2.41	.188	.57
40	TOP	0.00	0.00	0.00	.56	1.21	10.89	35.63	22.06	14.82	6.87	3.96	0.00		1.89	.270	1.94	.252	.56

Table C-1. Distribution of size classes by frequency percentages.--Continued

REFERENCE		SIZE CLASS													STATISTICAL PARAMETERS				
CORE NO.	INT (FT)	-1.000 -2.000	-.500 -1.414	.000 1.000	.500 .707	1.000 .500	1.500 .354	2.000 .250	2.500 .177	3.000 .125	3.500 .088	4.000 .062	PAN	PHI MM.	MEDIAN PHI	MEDIAN MM.	MEAN PHI	MEAN MM.	S.D. PHI
41	TOP	0.00	4.56	9.33	5.75	15.13	14.70	15.00	10.60	8.27	10.93	5.67	0.00		1.51	.350	1.56	.339	1.21
43	TOP	0.00	0.00	0.00	.54	.52	7.60	11.91	15.38	30.39	19.77	4.88	0.00		2.69	.155	2.57	.168	.84
44	TOP	0.00	0.00	0.00	.22	1.86	9.55	11.76	28.21	40.25	8.14	0.00	0.00		2.48	.179	2.35	.196	.56
45	TOP	0.00	.69	.75	1.51	4.91	5.79	25.81	36.51	23.03	0.00	0.00	0.00		2.16	.224	2.02	.246	.65
45	-4.0	0.00	0.00	0.00	0.00	0.00	.04	13.96	49.49	33.57	2.94	0.00	0.00		2.37	.193	2.38	.192	.33
46	TOP	0.00	0.00	0.00	0.00	0.00	10.08	41.22	26.90	10.01	5.20	0.00	0.00		1.88	.272	1.98	.254	.89
47	TOP	0.00	0.00	0.00	.75	.39	6.92	19.46	20.19	23.17	20.65	8.48	0.00		2.55	.171	2.51	.176	.72
48	TOP	0.00	0.00	0.00	0.00	.89	24.39	27.38	20.90	11.79	9.05	5.00	0.00		1.94	.260	2.09	.235	.71
48	-4.0	0.00	0.00	0.00	0.00	.10	4.85	20.41	29.62	23.28	12.76	1.39	0.00		2.28	.206	2.28	.205	.61
49	TOP	0.00	0.00	.95	1.33	24.31	42.87	15.10	8.37	7.20	0.00	0.00	0.00		1.21	.432	1.37	.388	.60
49	-2.0	0.00	.16	1.13	.74	.23	10.02	18.92	28.38	20.29	14.47	9.66	0.00		2.38	.192	2.39	.190	.79
50	TOP	0.00	0.00	0.00	0.00	.25	9.07	38.14	22.34	17.89	12.32	0.00	0.00		2.05	.241	2.17	.222	.59
51	TOP	0.00	0.00	0.00	.27	1.94	19.34	18.30	26.67	19.54	12.72	1.23	0.00		2.18	.221	2.19	.220	.68
52	TOP	0.00	0.00	0.00	.42	.91	13.50	19.83	29.43	21.01	11.91	3.00	0.00		2.27	.208	2.27	.208	.65
52	-2.0	0.00	0.00	0.00	.04	.45	10.03	34.24	31.73	11.34	4.17	0.00	0.00		1.95	.258	1.98	.253	.50
52	-4.0	0.00	0.00	0.00	0.00	.46	1.25	32.19	33.59	25.08	7.43	0.00	0.00		2.26	.209	2.25	.210	.49
53	TOP	0.00	.71	.37	.19	.06	1.92	8.15	12.93	34.95	31.91	8.81	0.00		2.89	.135	2.78	.146	.66
53	-4.0	0.00	0.00	0.00	0.00	.15	1.50	6.83	8.72	18.78	49.18	17.17	0.00		3.21	.108	3.05	.120	.54
55	-10	0.00	0.00	0.00	.12	.07	.79	1.82	10.76	23.60	41.39	21.45	0.00		3.16	.112	3.07	.119	.50
55	TOP	0.00	.34	2.51	5.75	35.70	22.72	14.15	8.32	8.12	2.40	0.00	0.00		1.10	.465	1.28	.411	.78
55	-2.0	0.00	.23	.19	.07	.58	5.97	26.77	26.53	19.58	13.04	7.05	0.00		2.31	.201	2.36	.195	.69
56	TOP	0.00	.19	1.88	3.79	16.73	29.38	20.34	15.67	7.30	4.72	0.00	0.00		1.46	.363	1.56	.340	.75
56	-2.0	0.00	.06	.11	.56	1.12	5.48	44.16	30.35	15.34	2.81	0.00	0.00		1.98	.254	2.03	.246	.50
56	-4.0	0.00	0.00	0.00	.03	.70	1.21	45.09	38.00	12.56	2.42	0.00	0.00		2.03	.245	2.00	.248	.42
56	-6.0	0.00	.03	1.01	9.08	15.41	27.21	18.44	14.95	11.42	2.40	0.00	0.00		1.45	.365	1.53	.346	.79
56	-8.0	0.00	1.87	15.69	27.45	15.30	11.59	9.06	7.07	9.67	2.30	0.00	0.00		.84	.641	.92	.529	1.02
56	-9.6	0.00	1.19	1.96	1.45	9.05	11.77	13.46	22.92	22.30	9.99	5.89	0.00		2.25	.210	2.12	.231	.94
57	TOP	0.00	0.00	.52	2.70	11.78	22.20	20.33	19.14	11.20	9.23	2.85	0.00		1.77	.293	1.88	.273	.83
57	-2.0	0.00	2.20	11.89	15.89	30.39	9.97	9.19	11.46	9.41	0.00	0.00	0.00		.78	.583	1.02	.493	.94
57	-4.0	0.00	0.00	0.00	0.00	.97	1.95	12.32	19.84	27.44	25.33	12.15	0.00		2.76	.148	2.71	.153	.66
58	TOP	0.00	0.00	0.00	1.32	3.31	35.08	16.90	21.57	14.98	6.84	0.00	0.00		1.84	.280	1.88	.272	.69
58	-2.0	0.00	0.00	.05	.59	.26	1.22	23.84	29.95	28.37	15.73	0.00	0.00		2.42	.187	2.41	.188	.55
59	TOP	0.00	1.23	1.23	.53	9.91	30.18	14.84	18.59	13.52	9.97	0.00	0.00		1.76	.295	1.82	.283	.84
60	TOP	0.00	.32	.80	.36	1.48	6.47	26.85	26.02	23.23	8.76	4.09	0.00		2.27	.208	2.26	.209	.70
60	-4.0	0.00	3.28	8.07	12.36	20.45	15.85	9.03	17.23	12.87	2.80	0.00	0.00		1.19	.438	1.34	.395	1.00
60	-8.0	0.00	1.21	10.96	25.17	21.77	9.74	10.84	10.27	10.09	0.00	0.00	0.00		.73	.601	1.01	.497	.94
60	-10	0.00	0.00	0.00	0.00	0.00	.17	39.03	31.50	14.85	8.31	6.13	0.00		2.16	.223	2.29	.204	.59
61	TOP	0.00	0.00	0.00	0.00	1.03	15.29	23.01	31.21	14.67	10.19	0.00	0.00		2.16	.223	2.16	.223	.59
61	-1.0	0.00	3.43	0.00	10.02	14.22	12.05	11.13	20.11	13.49	0.89	0.00	0.00		1.65	.319	1.55	.342	1.09
61	-1.0	0.00	.78	4.20	30.59	25.53	17.13	8.83	8.23	4.00	0.00	0.00	0.00		.79	.577	.95	.519	.75
61	-2.5	0.00	1.25	3.48	21.74	33.72	11.50	9.04	7.90	8.20	3.50	0.00	0.00		.80	.574	1.09	.470	.88
61	-2.0	0.00	1.36	6.91	32.90	22.08	14.44	9.02	5.72	7.55	0.00	0.00	0.00		.67	.631	.91	.533	.83
61	-4.0	0.00	0.00	.34	.36	.08	1.47	14.93	43.03	27.97	11.82	0.00	0.00		2.38	.192	2.41	.189	.49
62	TOP	0.00	0.00	.08	.51	1.79	10.52	17.81	26.27	22.87	14.14	0.00	0.00		2.27	.208	2.22	.214	.67
63	TOP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.16	53.05	38.61	2.18	0.00		2.93	.132	2.93	.131	.29
64	TOP	0.00	1.58	1.01	.03	.76	8.19	16.88	19.80	36.04	15.10	0.00	0.00		2.52	.174	2.33	.199	.75
65	TOP	0.00	0.00	0.00	.10	2.62	17.60	15.68	26.62	27.45	9.93	0.00	0.00		2.31	.202	2.20	.218	.65
66	TOP	0.00	.73	2.00	1.83	1.96	14.59	11.72	20.51	31.31	15.40	0.00	0.00		2.44	.184	2.22	.214	.84
70	TOP	0.00	.17	.97	.06	.51	4.99	14.46	23.59	41.29	13.96	0.00	0.00		2.56	.169	2.44	.185	.61

Table C-1. Distribution of size classes by frequency percentages.--Continued

REFERENCE		SIZE CLASS												STATISTICAL PARAMETERS				
CORE NO.	INT (FT)	-1.000 -2.000	-.500 -1.414	.000 -1.000	.500 -.707	1.000 -.500	1.500 -.354	2.000 -.250	2.500 -.177	3.000 -.125	3.500 -.088	4.000 -.062	PAN PHI	PAN MM.	MEDIAN PHI	MEDIAN MM.	MEAN PHI	MEAN MM.	S.D. PHI
71	TOP	0.00	0.00	.15	1.02	1.70	22.44	24.04	29.77	15.45	5.38	0.00	0.00		2.01	.248	1.99	.251	.60
71	-2.0	0.00	0.00	.48	1.04	5.35	47.07	27.27	14.99	3.83	0.00	0.00	0.00		1.48	.363	1.54	.343	.49
71	-4.0	0.00	0.00	0.00	0.00	0.00	1.75	34.26	21.90	18.35	17.67	10.07	0.00		2.29	.205	2.45	.183	.69
71	-6.0	0.00	.27	1.07	.56	1.85	28.07	39.48	23.76	4.94	0.00	0.00	0.00		1.69	.310	1.72	.304	.50
72	TOP	0.00	0.00	0.00	0.00	.76	5.60	27.82	28.38	18.43	10.70	8.37	0.00		2.29	.205	2.36	.195	.68
72	-4.0	0.00	9.11	7.05	.69	1.11	2.86	13.79	13.40	18.84	20.00	13.16	0.00		2.55	.170	2.16	.228	1.36
72	-6.0	0.00	0.00	0.00	0.00	0.00	1.14	6.05	12.55	23.32	33.88	23.07	0.00		3.11	.116	3.01	.125	.57
72	-8.0	0.00	0.00	0.00	0.00	0.00	0.00	1.36	9.88	23.69	45.19	20.28	0.00		3.16	.112	3.11	.115	.43
72	-10.0	0.00	0.00	0.00	0.00	0.00	0.00	6.84	28.79	37.35	18.25	8.77	0.00		2.67	.158	2.71	.153	.50
73	TOP	0.00	0.00	0.00	1.07	30.16	22.52	22.08	12.91	8.65	0.00	0.00	0.00		1.24	.424	1.38	.385	.59
73	-2.0	0.00	0.00	.37	1.29	1.35	18.74	19.97	21.95	13.72	13.20	9.41	0.00		2.16	.224	2.25	.210	.82
73	-4.0	0.00	.81	.77	.18	.52	1.14	2.27	8.90	23.57	39.25	22.79	0.00		3.15	.113	3.01	.124	.69
74	TOP	0.00	.50	.07	.43	1.08	4.30	10.95	27.29	36.44	12.34	0.00	0.00		2.48	.179	2.36	.194	.64
74	-4.0	0.00	0.00	0.00	.01	.09	.87	2.03	5.78	18.42	39.87	32.84	0.00		3.30	.101	3.17	.111	.53
74	-12.0	0.00	1.43	27.96	22.34	2.62	1.97	3.91	4.69	7.90	13.81	13.36	0.00		.83	.744	1.38	.384	1.59
75	TOP	0.00	0.00	0.00	0.00	1.08	10.03	17.16	25.69	29.37	10.92	5.75	0.00		2.44	.185	2.39	.191	.66
76	TOP	0.00	0.00	3.12	3.09	11.95	30.93	20.94	13.34	5.92	8.89	2.21	0.00		1.52	.348	1.67	.314	.86
77	TOP	0.00	.73	1.71	.99	15.85	32.10	16.99	10.20	8.15	5.29	0.00	0.00		1.48	.359	1.63	.323	.75
78	TOP	0.00	0.00	.07	.76	1.78	25.93	38.10	23.13	10.23	0.00	0.00	0.00		1.73	.302	1.81	.286	.50
78	-2.0	0.00	0.00	0.00	0.00	.75	24.46	22.39	20.66	11.99	10.99	8.76	0.00		2.05	.241	2.18	.221	.79
82	TOP	0.00	0.00	.77	.14	3.79	20.89	15.35	17.88	15.26	15.75	10.17	0.00		2.27	.207	2.26	.209	.90
84	TOP	0.00	0.00	0.00	.26	5.85	43.60	21.29	13.04	6.89	9.05	.02	0.00		1.51	.352	1.74	.299	.69
84	-6.1	0.00	0.00	.09	1.32	1.52	3.17	8.62	9.36	17.91	35.48	22.53	0.00		3.13	.115	2.89	.135	.76
85	TOP	0.00	.76	1.76	1.41	2.51	6.44	12.21	23.64	37.70	13.58	0.00	0.00		2.52	.175	2.32	.200	.76
86	TOP	0.00	0.00	.04	.33	3.10	52.61	23.23	15.48	5.21	0.00	0.00	0.00		1.44	.370	1.56	.338	.48
87	TOP	0.00	.72	2.69	22.26	35.22	14.42	8.80	7.12	8.97	0.00	0.00	0.00		.75	.595	1.05	.483	.80
89	TOP	0.00	0.00	0.00	.21	1.40	36.83	26.78	7.95	8.30	13.10	5.43	0.00		1.70	.308	1.97	.255	.81
91	-4.0	0.00	0.00	0.00	0.00	1.02	1.61	6.82	7.02	23.31	36.91	23.31	0.00		3.15	.113	3.02	.124	.62
92	TOP	0.00	0.00	0.00	0.00	0.00	5.50	25.37	25.68	21.93	12.67	8.85	0.00		2.36	.192	2.45	.183	.65

Table C-2. Sieve data in cumulative percent of stated diameter.

Core No.	Interval[1]	Diameter																
		phi	−4.0	−3.5	−3.0	−2.5	−2.0	−1.5	−1.0	−0.50	0.0	+0.50	+1.0	+1.5	+2.0	+2.5	+3.0	+3.5	+4.0
		mm	16.0	11.1	7.9	5.6	4.0	2.8	2.0	1.4	1.0	0.710	0.500	0.354	0.250	0.177	0.125	0.088	0.063
10	−10					2.1	5.2	10.1	15.2	24.0	39.0	70.4	93.4	95.7	96.1	97.1	99.7	99.8	99.9
12	−2				3.1	8.7	10.6	17.6	23.8	28.9	31.6	34.9	41.3	51.2	67.8	81.6	92.4	98.8	99.4
15	−8		6.0	7.5	10.7	13.4	16.5	20.3	23.4	25.4	26.4	27.2	28.0	29.7	40.0	65.0	89.5	96.7	98.6
16	−2			3.1	5.4	10.4	15.3	22.2	27.8	31.3	33.1	34.4	36.5	43.6	73.3	94.2	99.3	99.8	99.9
25	−2				1.2	3.5	8.0	13.2	17.3	21.5	26.6	33.6	42.3	48.9	55.4	63.0	74.6	86.9	90.3
26	−4				3.1	5.1	7.1	10.9	14.3	18.4	23.2	29.8	36.7	40.5	46.6	54.2	61.8	83.5	88.4
28	−6				4.3	11.7	18.0	21.7	24.5	27.1	29.2	32.0	36.3	38.7	41.0	45.5	63.6	83.1	93.7
29	−8				5.4	13.5	19.9	26.6	32.5	37.9	42.7	48.2	59.0	71.0	84.9	90.5	94.6	99.2	99.6
30	−4				19.2	25.8	29.6	33.3	34.9	36.6	38.8	44.1	57.7	74.3	89.1	95.0	98.3	99.8	99.9
30	−6			5.9	30.0	44.7	52.6	58.0	61.7	65.1	68.0	72.4	79.7	88.3	92.7	94.0	96.3	98.4	98.8
33	Top		35.0	36.6	39.1	41.6	46.0	49.8	53.4	57.8	63.1	69.2	77.3	86.5	93.4	96.0	97.2	98.1	98.6
36	−8		6.6	9.6	19.6	27.2	28.9	32.1	33.7	35.5	36.7	38.3	41.2	47.0	56.8	74.7	93.2	98.4	99.2
39	Top				1.3	3.5	6.9	13.0	20.0	25.2	28.7	33.1	42.2	60.6	82.1	91.6	95.1	98.3	99.5
41	Top		38.8	46.1	50.4	52.2	55.1	58.4	59.9	61.1	61.9	63.1	66.6	74.0	86.2	92.4	95.6	97.2	98.0
41	−1		40.5	45.4	50.0	52.0	55.0	59.5	61.5	62.7	63.7	64.8	66.8	71.4	79.6	85.5	90.7	93.7	95.5
42	Top				2.1	7.0	21.2	47.2	61.6	66.9	68.8	71.5	76.4	84.6	92.7	95.0	96.0	98.0	99.0
42	−1				22.9	29.7	36.9	49.1	63.9	72.2	75.0	78.0	82.5	89.0	96.2	98.6	99.1	99.3	99.5
56	−6				1.4	4.9	5.8	7.9	10.7	14.4	18.9	24.9	35.0	49.6	71.4	84.6	96.0	99.2	99.6
56	−8			8.2	9.1	10.6	12.4	15.6	19.9	26.5	33.5	46.3	61.1	72.4	81.5	87.5	95.1	99.2	99.6
57	−2				1.9	4.0	6.5	10.1	14.1	19.1	25.8	36.1	53.0	69.3	77.7	85.0	98.5	99.7	99.8
60	−6				3.0	5.7	7.3	10.2	13.2	17.1	22.6	31.0	43.1	54.6	67.2	79.7	94.9	99.0	99.4
60	−8				0.42	1.9	3.6	6.4	10.6	17.2	27.8	40.8	53.6	62.1	71.3	85.4	96.7	98.7	99.0
61	−2		4.4	5.1	8.0	8.5	10.1	11.2	13.8	18.6	96.5	38.4	59.3	79.5	92.4	96.4	99.0	99.7	99.9
61	−3					0.54	0.90	1.5	2.8	5.9	13.6	28.7	51.6	69.2	85.5	92.6	97.5	99.5	99.9
74	−12					1.9	4.5	11.4	25.2	43.8	56.6	63.8	67.5	70.7	74.4	77.4	80.8	83.6	88.0
81	Top		27.0	55.9	68.9	74.3	78.0	82.1	85.8	89.7	92.9	95.5	96.9	97.7	98.7	99.2	99.5	99.7	99.8
83	Top		40.7	47.6	56.4	62.3	66.3	69.9	71.8	73.5	74.5	76.1	78.2	81.2	88.8	96.8	99.4	99.7	99.8
84	−4			3.3	7.7	18.5	38.3	62.4	71.3	74.8	77.0	79.3	82.7	86.0	88.7	90.3	92.3	93.5	96.3
87	Top					1.8	5.4	7.7	9.3	12.2	18.4	34.8	64.0	81.3	89.0	93.0	98.2	99.1	99.3

[1]Distance in feet from top of core.

Meisburger, Edward P.
Sand resources of southeastern Lake Michigan / by Edward P. Meisburger, S. Jeffress Williams...[et al.]. - Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.
61 p. : ill. ; 27 cm. - (Miscellaneous report - U.S. Coastal Engineering Research Center ; no. 79-3)
About 2,072 square kilometers of the eastern shore of Lake Michigan between Manistee, Michigan, and Burns Harbor, Indiana, was surveyed to assess potential sand and gravel resources. Silt and clay deposits are the most common subbottom sediment type. Results showed that the highest potential for sand is in the area between Whitehall and Saugatuck, Michigan.
1. Geomorphology - Lake Michigan. 2. Sand sources - Lake Michigan. 3. Seismic reflection. I. Title. II. Williams, S. Jeffress, joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 79-3.

TC203 .U581mr no. 79-3 627

Meisburger, Edward P.
Sand resources of southeastern Lake Michigan / by Edward P. Meisburger, S. Jeffress Williams..,[et al.]. - Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.
61 p. : ill. ; 27 cm. - (Miscellaneous report - U.S. Coastal Engineering Research Center ; no. 79-3)
About 2,072 square kilometers of the eastern shore of Lake Michigan between Manistee, Michigan, and Burns Harbor, Indiana, was surveyed to assess potential sand and gravel resources. Silt and clay deposits are the most common subbottom sediment type. Results showed that the highest potential for sand is in the area between Whitehall and Saugatuck, Michigan.
1. Geomorphology - Lake Michigan. 2. Sand sources - Lake Michigan. 3. Seismic reflection. I. Title. II. Williams, S. Jeffress, joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 79-3.

TC203 .U581mr no. 79-3 627

Meisburger, Edward P.
Sand resources of southeastern Lake Michigan / by Edward P. Meisburger, S. Jeffress Williams...[et al.]. - Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.
61 p. : ill. ; 27 cm. - (Miscellaneous report - U.S. Coastal Engineering Research Center ; no. 79-3)
About 2,072 square kilometers of the eastern shore of Lake Michigan between Manistee, Michigan, and Burns Harbor, Indiana, was surveyed to assess potential sand and gravel resources. Silt and clay deposits are the most common subbottom sediment type. Results showed that the highest potential for sand is in the area between Whitehall and Saugatuck, Michigan.
1. Geomorphology - Lake Michigan. 2. Sand sources - Lake Michigan. 3. Seismic reflection. I. Title. II. Williams, S. Jeffress, joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 79-3.

TC203 .U581mr no. 79-3 627

Meisburger, Edward P.
Sand resources of southeastern Lake Michigan / by Edward P. Meisburger, S. Jeffress Williams...[et al.]. - Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.
61 p. : ill. ; 27 cm. - (Miscellaneous report - U.S. Coastal Engineering Research Center ; no. 79-3)
About 2,072 square kilometers of the eastern shore of Lake Michigan between Manistee, Michigan, and Burns Harbor, Indiana, was surveyed to assess potential sand and gravel resources. Silt and clay deposits are the most common subbottom sediment type. Results showed that the highest potential for sand is in the area between Whitehall and Saugatuck, Michigan.
1. Geomorphology - Lake Michigan. 2. Sand sources - Lake Michigan. 3. Seismic reflection. I. Title. II. Williams, S. Jeffress, joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 79-3.

TC203 U581mr no. 79-3 627